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A Quarterly Forecasting Model for U.S. Agriculture

Subsector Models for Corn, Wheat, Soybeans, Cattle, Hogs, and Poultry

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Abstract

A newly developed econometric model for the U.S. agriculture sector is used in outlook and policy analysis. It provides quarterly forecasts for major agricultural commodities and is used in impact analysis where alternative scenarios are simulated and compared with the model's base forecast. Subsector models have been completed for six commodities (corn, wheat, soybeans, cattle, hogs, and poultry) chosen because of their importance in cross-commodity linkages within the agriculture sector. Although relatively small, the agriculture model described in this report is large enough to help identify links within the agriculture sector and links with other sectors.

Keywords: Econometric model, quarterly forecasts, corn, wheat, soybeans, cattle, hogs, poultry.

Acknowledgments

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Summary

A newly developed econometric model for the U.S. agriculture sector is used in outlook and policy analysis; it provides quarterly forecasts for major agricultural commodities and is used in impact analysis where alternative scenarios are simulated and compared with the model's base forecast. Subsector models have been completed for six commodities (corn, wheat, soybeans, cattle, hogs, and poultry) chosen because of their importance in cross-commodity linkages within the agricultural sector. Although relatively small, the agriculture model described in this report is large enough to help identify links within the agriculture sector and links with other sectors.

A presentation of the general model structure for each commodity is followed by a discussion of the individual equations used. Quarterly equations were estimated for each commodity's price and major supply and utilization components. Equations for annual variables, such as planted acreages in the crop subsectors and January 1 cow inventories in the cattle subsector, were estimated in an annual framework. These variables were then incorporated into the quarterly framework by entering the annual equation into the model in the appropriate quarter each year, while setting the variable equal to zero in the other quarters.

Simulations of the full model (combining the six subsector models) showed it performed quite well over the estimation period. Its performance was less satisfactory in simulations beyond the estimation period, although the major supply and utilization aggregates performed reasonably well.

Subsector models for dairy and eggs are expected to be completed over the next year in addition to linkages to models for the major agriculture sector aggregates. Subsequent development will depend on demand, but may include subsector models for cotton, barley, oats, and sorghum.

A Quarterly Forecasting Model for U.S. Agriculture

Subsector Models for Corn, Wheat, Soybeans, Cattle, Hogs, and Poultry

Introduction

ERS has developed a quarterly forecasting model of the U.S. agriculture sector to aid in its situation and outlook program and related activities. Such a model is needed to serve as an analytical tool in commodity analysis, to improve the consistency of ERS forecasts, and to improve the efficiency of the ERS forecasting process (*23*). An important feature of the model is that it parallels the ERS situation and outlook forecasting process: it has explicit linkages between the crop and livestock sectors, it uses macroeconomic variables as exogenous inputs, and it produces outputs needed to generate aggregate agriculture sector indicators. As a consequence, the quarterly model has two major application areas. First, it serves as a supplemental tool to assist commodity analysts in developing the short-term outlook for the agriculture sector. Second, it is a tool in shortrun impact analyses where alternative scenarios are simulated and compared with the current base forecast.

The ERS Situation and Outlook Program and Model Design

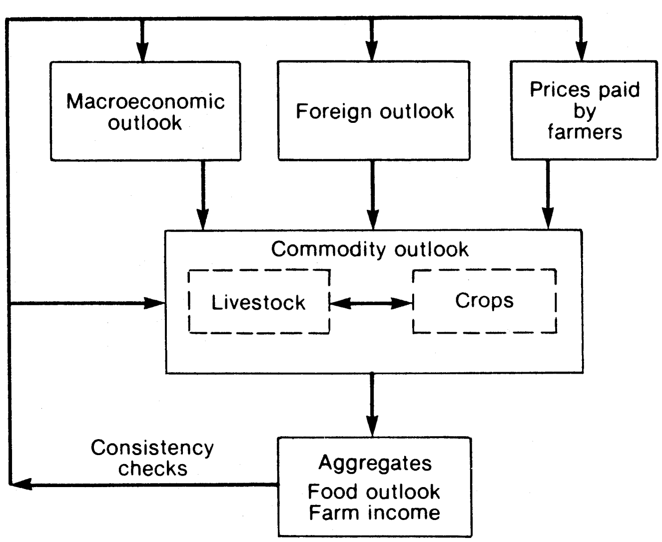
Because the quarterly agriculture forecasting model has been designed to be an integral part of the ERS situation and outlook program and related activities, a review of the agency's monthly forecasting process will illustrate some model characteristics.

At the start of each month's forecasting activities, projections are made for major macroeconomic variables, prices paid by farmers, and various foreign outlook variables. These data are then used by the domestic commodity analysts to derive supply, utilization, and price projections for agricultural commodities. Various analysts interact, especially livestock and feed grain analysts, to assure consistency of the commodity forecasts. Aggregate agriculture sector indicators are then derived, including forecasts for farm income, food prices, and food consumption. These aggregate projections are analyzed for consistency with macroeconomic projections; any inconsistencies are again resolved through interaction among various analysts. The final product is a set of forecasts consistent between subsectors within agriculture and between the aggregate agriculture sector and the macroeconomic setting. This process is depicted in figure 1.

This monthly forecasting process has guided the design and development of the quarterly agriculture forecasting model. The quarterly model has been viewed as a separate block within a larger forecasting system as depicted in figure 2. This view facilitates the incorpora-

Figure 1

The ERS Monthly Forecasting Process



tion of the model into situation and outlook activities. By treating the agriculture sector as a separate block, the variables projected and available at the start of the monthly forecasting process—macroeconomic, foreign, and prices paid—are treated as exogenous inputs to the agriculture sector model. Within the agriculture block, interaction between various subsectors, particularly livestock and feeds, is critical to the model's structure. Results from the agriculture sector model can be used as inputs to independently derived, already-existing models of the major agriculture sector aggregates. Feedbacks and consistency checks can be performed as needed through iteration.

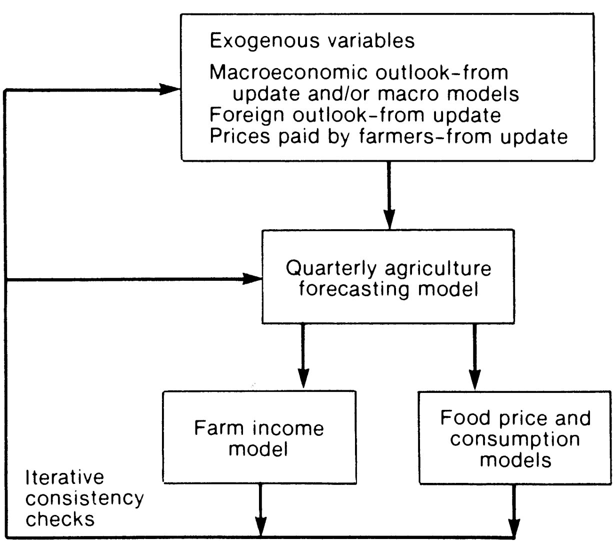
Applications

The quarterly agriculture forecasting model is used in the ERS monthly forecasting process and in responding to impact analyses requiring quick turnaround. Because these application areas are primarily short term in nature, the quarterly model has been designed to forecast three to six quarters ahead.

In the monthly forecasting process, model estimates serve as an additional source of information for the commodity analysts in making their projections. The model focuses on the major variables important for each commodity and serves as a useful tool for making projections, thereby complementing the work of commodity analysts. Two major benefits to the monthly forecasting activities are derived from the model. First, estimates are available to the analysts early in the monthly forecasting process. Second, last minute changes during the forecasting process can be easily incorporated into the agriculture sector projections with consistency assured through linkages between the various subsectors. These benefits arise largely because the model is computerized and has a quick turnaround capability.

Figure 2

The Role of the Quarterly Agriculture Forecasting Model



In impact analysis applications, alternative scenarios can be easily run, again with quick turnaround. These scenarios are generated by changing exogenous assumptions, by restricting endogenous responses (using slope and/or intercept shifters), and/or by exogenizing endogenous variables. Simulation results from alternative scenarios can be compared with the model's base forecast for that month to form the basis of evaluating the impact.

As illustrated in the review of the ERS monthly forecasting process, analysts interact to assure consistency among forecasts. This process, however, requires time that may not always be available in meeting the deadlines of impact analysis studies. This time constraint results in either inconsistent forecasts being used or deadlines being missed. Because the model easily accommodates alternative scenarios, substantial time-savings and improved forecast consistency are gained.

Development Phases

The first developmental phase of the quarterly agriculture forecasting model is presented in this report. Commodities covered are corn, wheat, soybeans, soybean meal, soybean oil, cattle, hogs, broilers, and turkeys. These commodities have provided a relatively small-scale agriculture sector model, yet the model has been large enough to be useful in identifying linkages within the agriculture sector as well as linkages from the macroeconomy to the agriculture sector.

Additional development will add greater detail to the model along two general lines. One will be the inclusion of more commodities, such as dairy, eggs, cotton, barley, oats, and sorghum. The other will be the development of explicit linkages to other econometric models such as macroeconomic models and aggregate agriculture sector models for farm income, food prices, and food consumption.

Model Structure

The general structure used to develop the crop subsectors is a disequilibrium model with ending stocks clearing the market. A disequilibrium model is more appropriate for crops in a quarterly framework than in a longer run (annual) framework because, with shorter time periods, markets are more likely to be in adjustment rather than approximating equilibrium. Incomplete market adjustments from quarter to quarter largely reflect the lag structures in supply and demand functions which prevent complete adjustments in the short run. Thus, part of the ending stocks from each quarter are likely the result of incomplete market adjustments.

Figures 3 through 5 show the structures of the corn, wheat, and soybean sector models. Supply and use are determined from estimated equations for their components, price is determined using an autoregressive formulation, and ending stocks clear the market—they are the residual of supply minus use.

The soybean sector is more complex than the corn and wheat sectors because it is linked to the soybean meal and soybean oil product markets through crushings and prices. Each product market also uses a disequilibrium model with stocks derived as a residual (see fig. 5). Soybean crushing is a derived demand primarily used to supply soybean meal for feed use and export. Consequently, domestic soybean meal demand "drives" the soybean sector by being used to determine meal production, soybean crush, and soybean oil production.

The soybean sector structure also provides a full quarterly supply and use balance sheet for soybeans that is not available elsewhere. Problems arise in accommodating the soybean and product markets because of the timing of available data. Soybean stocks data are reported for September 1, January 1, April 1, and June 1, giving uneven quarters—a 4-month quarter, a 2-month quarter, and two 3-month quarters. On the other hand, the product market data are reported on even 3-month quarters throughout their marketing years (each marketing year beginning October 1). As a result, the quarterly balance sheet for soybeans must fit the uneven quarters necessitated by the stock reporting dates, yet it must also be linked with the even quarters of the product market data. To do this, two different, though related, crush series are maintained by the model: crush used in the soybean balance sheet is on the uneven-quarter basis; crush used for the product markets is on the even-quarter basis.

Feasibility constraints are imposed on the crop sector models in simulations to assure that market-clearing stocks are not negative. For corn and wheat, the feed

Figure 3

Corn Sector Structure

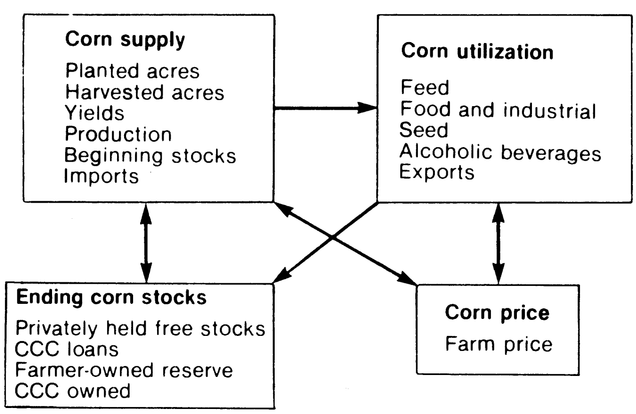
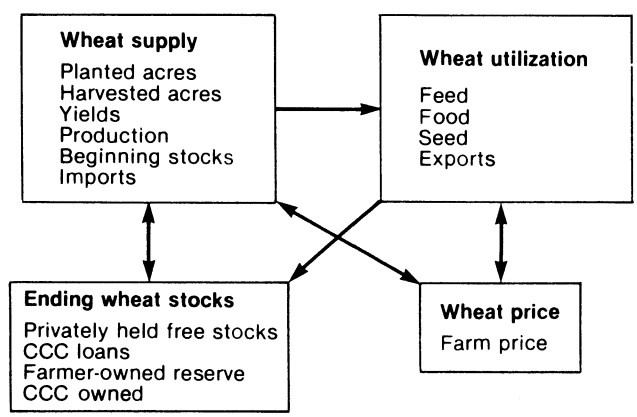


Figure 4

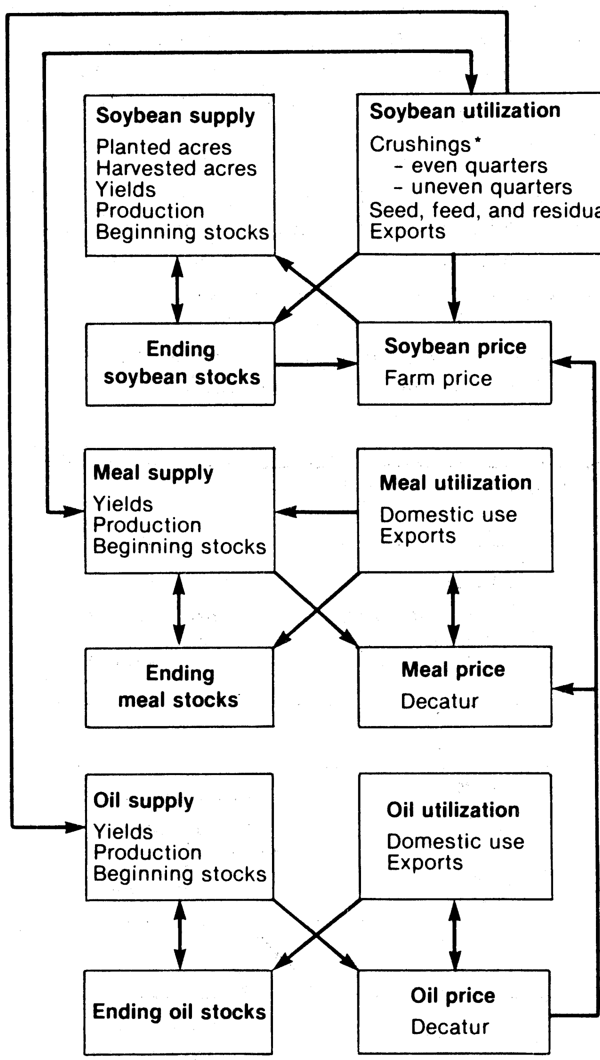
Wheat Sector Structure



demand equation is allowed to operate as long as the implied privately held free stock residual is not negative. However, if the feed demand equation implies a negative privately held free stock, feed demand is set at the level that results in privately held free stocks equalling zero. A more involved and stronger constraint has been included in the soybean sector reflecting the more complex model structure and the use of an inverse stocks-to-use ratio in the soybean price equation.

Figure 5

Soybean Sector Structure



*Even-quarter crushings used for product market linkages; uneven-quarter crushings used for soybean supply and use balance sheet.

The domestic soybean meal demand equation is allowed to operate as long as the implied soybean crush does not bring ending soybean stocks below 800 million bushels on December 31, 550 million bushels on March 31, 300 million bushels on May 31, and 50 million bushels on August 31. These levels were chosen to assure ample availability of soybean supplies through the marketing year to meet crushing and export demands.

An interesting aspect of the crop models is the incorporation of annual variables into the quarterly framework. Production is derived in an annual framework using acres planted, acres harvested, and yields. Annual production is then embedded into the quarterly framework. In the harvest quarter, production is added to beginning quarterly stocks and imports to derive quarterly supply; in the nonharvest quarters, production is set equal to zero.

Incorporating the annual variables into a quarterly framework has additional structural implications because of the lags involved between plantings and harvest. Production, yields, and harvested acreage all enter the crop sector models in harvest quarter. However, planted acreage takes place two or three quarters earlier and is included in the model then, using quarterly information known at that time. This differs from planting decision equations in many annual models which use variables from the previous marketing year, even though the previous marketing year is not completed at the time plantings occur. To illustrate, because of the lags between plantings, harvest, and marketings, formulations of planted acreage typically include a price expectations variable to represent expected returns. In "cobweb" formulations of expectations, many annual models use the previous marketing year's price even though plantings occur before the previous marketing year is completed. In contrast, implementation of a "cobweb" formulation of planted acreage in a quarterly framework allows information known by the planting quarter, which precedes the beginning of the corresponding crop year by two or three quarters, to be used. Consequently, the price expectations variable employed in the planted acreage equations is the price in the quarter immediately preceding the plantings quarter.

In the cattle sector model (fig. 6), breeding herd equations provide information about the capital stock from which cattle production is drawn. Constrained by the size of this capital stock (the breeding herd), estimated cattle production equations for feedlot placements, marketings, and fed and nonfed steer and heifer slaughter are used to derive total commercial slaughter in an identity. Beef production estimates are derived from those slaughter estimates which are added to beginning stocks and imports to derive supply. Ending cold storage stocks are estimated. Beef consumption is derived as a residual, following the procedure used for construction of the historical consumption data. Prices for feeder steers, fed steers, cattle, and calves are estimated using supplies and derived demand factors. Product market (retail) prices are not included as part of the quarterly model because they are derived in the aggregate block in the monthly update process in a stage-of-processing model utilizing the farm-level prices that are estimated here.

In the hog sector model (fig. 7), the number of sows farrowing determines the size of the pig crop which is used to estimate barrow and gilt slaughter. Total hog slaughter is then derived by adding breeding herd liquidations. Supplies, utilization, and stocks of pork and prices for hogs are estimated following a structure similar to that in the cattle sector.

In the poultry sector model (fig. 8), the number of pullets placed in hatchery supply flocks constrains the size of the broiler hatch which is then used to determine broiler production. Turkey production, however, is estimated directly. Supply, utilization, stocks, and prices for chickens and turkeys are each estimated following a structure similar to that in the cattle and hog sectors.

The livestock sector includes lags necessitated by the length of the biological production process. From breeding to slaughter takes about 27 months for cattle, 10 months for hogs, 3 months for broilers, and 6 months for turkeys. These temporal relationships are important for the appropriate modeling of the livestock sector and also affect the crop sector models in feed demand

Figure 6

Cattle Sector Structure

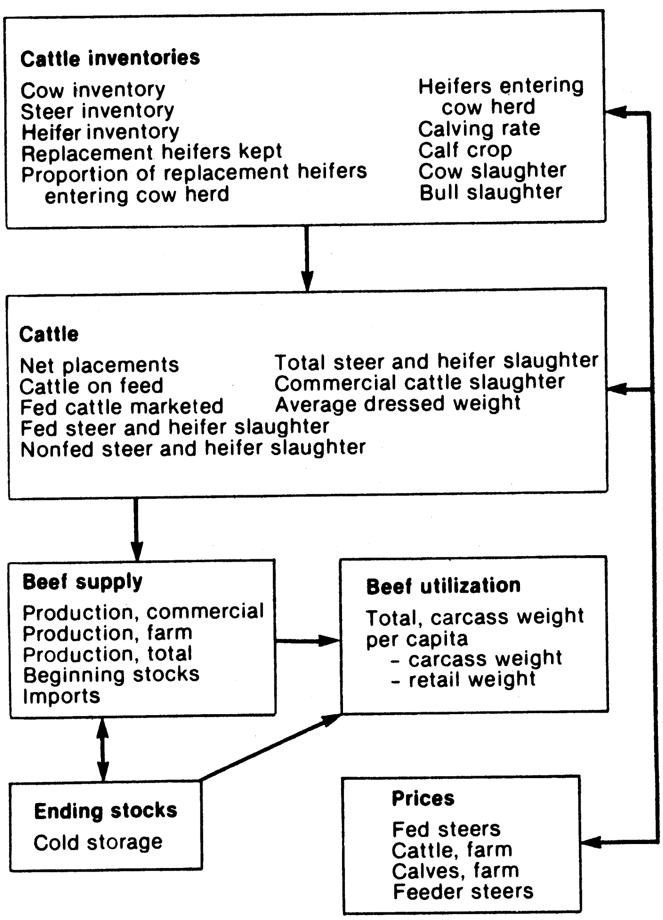
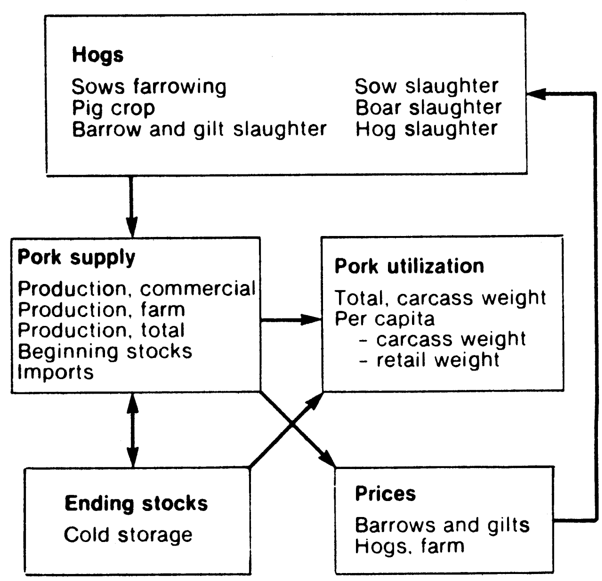


Figure 7

Hog Sector Structure



equations. As a consequence, expected returns and expected costs of production, represented by various lagged variables, play important roles. The lags also result in a higher amount of recursiveness in the model, which allows linkages between the crop and livestock subsectors to be made without the problems usually associated with a high degree of simultaneity.

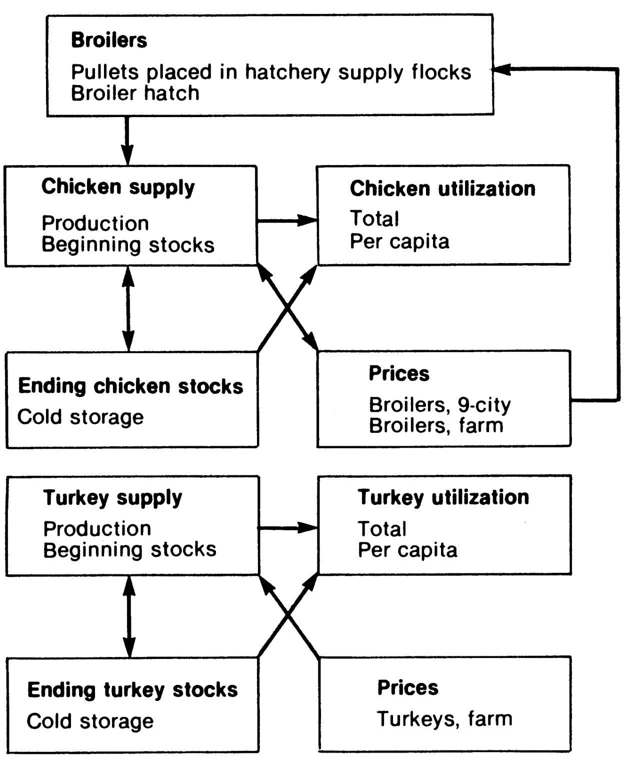
Equation Discussion[1]

All stochastic equations in the quarterly agriculture forecasting model were estimated using ordinary least squares regressions with the exception of the soybean meal price equation. For that equation, a principal components regression was used because of extreme collinearity in the regressors (*29*). For each equation,

[1]Specifications and summary statistics for each equation are shown in Appendix A. Appendix B shows an alphabetized list of variable names and definitions. Endogenous variables are shown first, followed by exogenous variables.

Figure 8

Poultry Sector Structure



t-statistics are reported in parentheses below the parameter estimates. The coefficient of determination (R^2), the root mean squared error (RMSE), and the coefficient of variation (CV) are reported along with the estimation period for each stochastic equation. The coefficient of variation and the root mean squared error are adjusted for degrees of freedom, but the coefficient of determination is unadjusted. For annual production equations in the crop sector, predicted values are calculated by using the estimated yield and harvested acres equations. The coefficient of determination, the root mean squared error, and the coefficient of variation for annual crop sector production equations are then derived, but these statistics are not adjusted for degrees of freedom.

Corn Sector

The corn sector in the model consists of 17 equations—8 stochastic equations and 9 identities. Equations for planted acreage, harvested acreage, and yields are estimated annually and, along with the production identity, are then incorporated into the quarterly framework in the appropriate quarters. The remaining 13 quarterly equations cover beginning stocks and total supply, total use and its major components, total and privately held ending stocks, and prices.

Acres Planted. Corn plantings primarily take place in the second quarter (April-May). However, the corn plantings equation enters the model in the first quarter because some plantings occur earlier and, as a result, the model's seed use equation for the January-March quarter depends on the planted acreage estimate. The planted acres equation makes use of the Houck-Ryan approach to incorporating price and policy variables in the model (*14*). This approach relies on effective price variables for payments of the crop produced and on diversion payment variables. In each case, adjustments are made to represent the commodity program requirements in place for a given year. Houck-Ryan effective price variables and diversion payment variables are used to represent market and policy incentives for planting corn and wheat. However, soybean farm price is appropriately used without policy adjustments because, over the estimation period, there were no soybean acreage control programs, the soybean farm price was higher than the support rate, and there was no paid diversion program for soybeans. A further discussion of the Houck-Ryan variables used and an illustration of their construction is presented in Appendix C.

Competition between corn, wheat, and soybeans for cropland is represented in the corn acres planted equation by the Houck-Ryan wheat variables and the soybean price. The supply response to corn price is a modified "cobweb" framework—acres planted is a function of the Houck-Ryan effective corn price which uses first quarter corn price.

The coefficients in the acres planted equation have the expected signs. Because crop price support and supply control programs have contradictory incentives, some discussion of the sign on the Houck-Ryan effective corn price parameter in the planted acres equation may be enlightening. The effective corn price represents incentives embodied in the set-aside rate, the expected season average price for the crop being planted, and the support level. The higher the set-aside rate, the lower the effective corn price and corn plantings. The higher the expected season average price, the higher the effective corn price and corn plantings. The higher the support level, the higher the effective corn price and corn plantings. A higher support level encourages greater participation by corn producers reducing corn plantings, but this reduction is offset by the cross commodity effects of additional acreage brought into the corn program from other uses.

The coefficients of the Houck-Ryan effective wheat price and the soybean price are about the correct magnitude relative to their estimated responses in their own planted acres equations, with cross-price effects less than own-price effects. Similarly, the Houck-Ryan effective corn price coefficient is about the correct magnitude relative to its estimated response in the soybean acres planted equation. However, it is less than the estimated cross price effect in the wheat planted acres equation. This is likely a result of correlation between the effective price for corn and the effective prices for other feed grains. The latter are not included in the model, yet their programs add to the measured cross-price effect in the wheat acreage equation while not affecting the own-price measure in the corn acreage equation.

Acres Harvested, Yields, and Production. Corn is harvested in the fourth quarter and is related to acres planted and yields. The yield equation follows a model of Lin and Davenport with Corn Belt weather variables playing an important role (*25*). The 1970 dummy variable adjusts for corn blight in the Southern States and the Corn Belt. The 1974 dummy variable adjusts for a late spring and early frost in the Lake States. Annual corn production is derived using an identity by multiplying harvested acres by yields. Because the acres planted coefficients in the acres harvested equation and the yield equation have opposite signs, the errors in those equations tend to be negatively correlated, offsetting each other in estimates of production.

Feed Use. USDA corn feed use data were adjusted for estimating this equation because these data reflect the corn marketing year which has uneven quarters—two 3-month quarters, one 2-month quarter, and one 4-month quarter. The adjusted corn feed data used in this model were calculated by multiplying feed use in the April-May quarter by 1.5 and feed use in the June-September quarter by 0.75. Thus, all four quarters of adjusted feed use data are on a prorated, 3-month equivalent basis. This adjustment is important for flow categories to assure that the parameter estimates are not affected by the unevenness of quarters represented in the published data, thereby allowing the measurement of response to explanatory variables to be comparable across quarters.

In the quarterly adjusted feed use equation, a four-quarter autoregressive term was included because of the relatively stable seasonality from year to year in corn feeding. The implied own-price elasticity is -0.46 and the implied cross-price elasticity with lagged soybean meal price is -0.12.[2] The negative sign on the cross-price elasticity is consistent with that implied by the corn price coefficient in the soybean meal domestic demand equation.

A negative cross-price elasticity suggests that corn and soybean meal are relatively poor substitutes or possibly complements in animal feeding. Although corn contains some protein, it is fed primarily as an energy source. Soybean meal, on the other hand, is fed for protein content and is a less concentrated, more expensive source of energy than feed grains such as corn or sorghum. Previous research has generally found a positive cross-price elasticity between low-protein and

[2]Because of the simultaneity in the model, elasticities and flexibilities derived from the single-equation parameter estimates are not strictly valid. Nonetheless, because of the large degree of recursiveness in the model, the elasticities and flexibilities presented provide reasonable approximations of the full model's impact multipliers.

high-protein feeds. These studies, however, used annual data and may have been reflecting that substitution in aggregate animal feeding is more feasible in the long run as producers adjust the mix of animals fed.

Quarterly adjusted feed use of corn also depends on the number of cattle on feed, as well as on a two-quarter lag of farm-level livestock prices to represent expected returns to feeding. The coefficient of the former variable implies a feeding rate for cattle of 42 bushels of corn per head. This compares favorably with the feeding rate of 45 bushels of corn equivalent grain assumed for Corn Belt cost of production estimates (*42*). Estimates of corn feed use on the uneven-quarter basis are derived by unadjusting the even-quarter estimates.

Food and Industrial Use. Per capita food and industrial use of corn is a function of deflated corn and wheat prices, trend, slope shifters, and intercept shifters. It is also estimated with adjusted even-quarter basis use data. Corn use in this category has undergone significant structural shifts over the last 15 years due to the growth of high fructose corn sirup use in processed foods and soft drinks and the increased ethanol production in response to gasohol subsidies (*28*). The trend, slope shift, and intercept shift variables are used to represent these factors. Estimates of total corn food use on the uneven-quarter basis are derived by unadjusting the even-quarter estimates and multiplying by population.

Alcoholic Beverage Use. Per capita alcoholic beverage use of corn is positively correlated with deflated income. The implied income elasticity is 0.62, implying that alcoholic beverages that use corn are normal goods. The dummy variables for the second and third quarters were used to adjust for the uneven quarters in the corn marketing year.

Seed Use. Seed use reflects annual planting decisions, so the corn seed use equation has been estimated annually. Quarterly seed use estimates are then derived by distributing the annual estimate over the four quarters of the year, putting 0 in the fourth quarter, 20 percent in the first and third quarters, and 60 percent in the second quarter. This seed use pattern reflects the distribution of plantings: no plantings in the fourth quarter, large plantings in the second quarter, and smaller plantings in the first and third quarters. The annual lead subscript reflects planted acreage for one year's crop taking place in the previous corn crop year, thereby using seed in the previous marketing year. The ratio of corn price to fertilizer costs (given the level of planted acres) represents an expected return of heavier seeding. The positive sign on annual trend reflects technological shifts in favor of larger seeding per acre through practices such as narrowing the distance between rows.

Stocks. Privately held free stocks are postulated to clear the market. They are calculated by subtracting use and exogenous ending stock components from supply. Total stocks are derived by adding privately held stocks to the exogenous ending stock components—stocks owned by the Commodity Credit Corporation (CCC), stocks under regular CCC loans, and stocks in the farmer-owned reserve.

Price. In the corn price equation, a one-quarter price lag is included to reflect short-term "stickiness" of prices in a quarterly framework. Price is also a function of total supply and use, with use adjusted to a prorated even-quarter basis as earlier discussed for feed use of corn.

The interaction variable of acres planted with the second- and third-quarter dummy variables and the July Corn Belt weather variables represent the effects on prices of preharvest information regarding developing crops. As new information becomes available about the crop being grown, resulting expectations about the size of the upcoming harvest affect prices in the months prior to harvest. Large planted acreage and favorable weather for crop development would lead to expectations of a large harvest, pushing corn prices down in the third quarter. Factors leading to expectations of a small harvest would be expected to push prices up.

The coefficients in the price equation imply that a 10-million-acre difference in planted acres causes a 3.5-cents-per-bushel difference in second- and third-quarter corn price, giving a price flexibility (evaluated at the means) of −0.12. A 1-degree difference in July Corn Belt temperature causes a 1-cent-per-bushel difference in third-quarter corn prices, implying a price flexibility of 0.33. A 1-inch difference in July Corn Belt precipitation causes a 14-cent-per-bushel difference in third-quarter corn prices, implying a price flexibility of −0.25. While these flexibilities are small, these variables will have additional impacts on prices in the following marketing year because of their effects on the size of the next harvest. The flexibilities shown here measure only the marginal price impacts of preharvest information before that information is realized in production, supply, and use.

Wheat Sector

The wheat sector in the model consists of 14 equations—7 stochastic equations and 7 identities. As for corn, equations for planted acreage, harvested acreage, and yields are estimated annually and, along with the production identity, are then incorporated into the quarterly framework in the appropriate quarters. The remaining 10 quarterly equations cover beginning stocks and total supply, total use and its major components, total and privately held ending stocks, and prices.

Acres Planted. Winter wheat plantings primarily take place in the fourth quarter (October-December), with spring wheat plantings primarily occurring in the following April-May quarter. Since the model makes no distinction between winter and spring wheat, the acres planted equation enters the model in the fourth quarter. Further, since third-quarter seed use depends on the estimate of planted acres, wheat plantings are determined in the model in the third quarter.

In a specification similar to the corn plantings equation, Houck-Ryan variables are used in estimating wheat acres planted.[3] The competition between wheat and corn for cropland is represented by the Houck-Ryan effective corn price. As with corn, the supply response to wheat price is a modified "cobweb" framework. Acres planted is a function of the Houck-Ryan effective wheat price which uses third-quarter wheat price. Houck-Ryan diversion payment variables are not included because they did not provide a statistically significant result.

The coefficients in the acres planted equation have the expected signs. As discussed for the corn sector, the Houck-Ryan effective wheat price is about the correct magnitude relative to its estimated response in the corn acres planted equation; own-price effects exceed cross-price effects. The corn price coefficient in the wheat planted acres equation, however, appears high relative to its own-price effect in the corn planted acres equation. The estimated cross-price effect in the wheat equation is probably too large. Programs for other feed grains probably result in effective prices for those grains being correlated with the effective price for corn, which would upwardly bias the magnitude of the corn cross-price coefficient.

Acres Harvested, Yields, and Production. Wheat harvest takes place in the third quarter and is positively correlated with acres planted. Yields are negatively correlated with acres planted and exhibit an upward trend. Excellent growing conditions in most wheat producing areas in 1971 are represented by the 1971 dummy variable. The dummy variable for 1974 adjusts for weather and disease problems. The dummy variable for 1978 adjusts for poor growing conditions in many winter wheat producing areas in late 1977 and 1978. Annual wheat production is then derived using an identity. As with corn, the negatively correlated errors in the acres harvested and yield equations, resulting from each using acres planted as an explanatory variable, tend to offset each other in the production estimates.

Feed and Residual Use. The wheat feed and residual use category includes a relatively large residual component that in many quarters results in negative numbers. The largest bona fide feed use occurs in the third quarter (June-September). Consequently, the estimated equation for feed and residual use has a different functional form for the third quarter than for the other three quarters under the assumption that a more systematic relationship could be found when the residual component is relatively smaller. The specification for first, second, and fourth quarters includes wheat prices, corn prices, and fed steer and heifer slaughter. While the inclusion of these variables is consistent with economic theory and their estimated coefficients have the expected signs, no interpretation of the magnitudes of those parameter estimates is given because the negative feed use observations affect those estimates and change the mean of the dependent variable needed for elasticity calculations.

The third-quarter wheat feed and residual use specification is similar to a June-September feed use study by Livezey (*27*). Wheat feeding depends on its own price; prices of substitute feeds, represented by

[3] The Houck-Ryan variables are discussed more completely in the corn sector discussion and in Appendix C.

corn and soybean meal; cattle on feed, representing a major animal group fed wheat; turkey production, as a proxy for poultry feeding (both broilers and turkeys); and a third-quarter 1976 dummy variable, adjusting for a period when a large wheat residual resulted in negative third-quarter feed and residual use. The third-quarter cattle on feed coefficient implies a feeding rate for cattle of about 34 bushels per head, a reasonable estimate. The poultry variable coefficient implies wheat accounts for about 80 percent of poultry feeding requirements, which is somewhat large. The own-price elasticity is −6.9, the cross-price elasticity with corn is 6.0, and the cross-price elasticity with soybean meal is 1.3. The first two of these estimates are about twice as large as estimates implied by Livezey's findings, but are consistent with those estimates in supporting the argument that wheat feeding is very sensitive to relative prices.

Food Use. Per capita food use of wheat is a function of deflated wheat and barley prices and seasonal and trend shifters. Food use is then derived by an identity. The small implied own-price elasticity of −0.03 and the cross-price elasticity of 0.04 likely result from the highly processed nature of most foods that use wheat so that the farm price has little effect on retail prices and final demand.

Seed Use. The seed use of wheat equation was estimated using observations from the second, third, and fourth quarters only because almost no planting occurs in the January-March quarter. Seed use depends on planted acreage, trend, and seasonal shifters. As with corn, the annual lead subscript reflects planted acreage for one year's crop taking place in the previous wheat crop year, and the positive sign on annual trend reflects technological shifts in favor of larger seeding per acre. The seasonal shifters are consistent with the quarterly pattern of plantings: heaviest in the third and fourth quarters for winter wheat with smaller plantings for spring wheat in the following second quarter (April-May).

Stocks. As with corn, privately held free stocks clear the market as a residual, subtracting use and exogenous ending stock components from supply. Total stocks are derived by adding privately held stocks to those exogenous ending stock components.

Price. Supply, adjusted (even-quarter) use, and a one-quarter lag of wheat price are included as explanatory variables in the wheat price equation. Two interaction variables of acres planted with the first- and second-quarter dummy variables are included to represent the effects on prices of preharvest information regarding developing crops. Their coefficients imply that a 10-million-acre difference in planted acres causes a 5.6-cents-per-bushel difference in wheat prices in the first quarter and a 10.6-cents-per-bushel difference in the second quarter, giving price flexibilities (evaluated at the means) of −0.13 and −0.26, respectively. Similar to those for corn, while these flexibilities are small, they measure only the marginal price impacts of preharvest information before that information is realized in the following crop year.

Soybean Sector

The soybean sector is larger than the corn and wheat sectors because it includes the soybean meal and soybean oil product markets. It consists of 28 equations (11 soybean, 8 soybean meal, and 9 soybean oil)—11 stochastic equations and 17 identities. As for corn and wheat, equations for planted acreage, harvested acreage, and yields are estimated annually and, along with the production identity, are then incorporated into the quarterly framework in the appropriate quarters. Seven quarterly equations cover supply, use, stocks, and prices for soybeans. Soybean crushings and prices provide the links to the soybean meal and soybean oil product markets where all 17 equations are quarterly.

Acres Planted. Soybean plantings enter the model in the second quarter. A modified "cobweb" framework is used to depict the supply response to soybean price. Acres planted is a function of expected prices, represented by first-quarter soybean prices deflated by a fertilizer price index. The competition between corn and soybeans for cropland is represented in the soybean acres planted equation by the Houck-Ryan corn price.[4] As in the corn and wheat sectors, the Houck-Ryan variable incorporates corn price and policy variables. For soybean farm prices, however, no policy adjustments are made because, over the estimation period, soybean farm prices were higher than the effective support rate and there was no paid diversion program for soybeans.

[4]The Houck-Ryan variables are discussed more completely in the corn sector discussion and in Appendix C.

The soybean price coefficient is about the correct order of magnitude relative to its estimated response in the corn acres planted equation. Also, the coefficient of the Houck-Ryan corn price has the expected sign and is the correct order of magnitude relative to its estimated response in the corn acres planted equation.

Acres Harvested, Yields, and Production. As with corn and wheat, the soybean acres harvested and yield equations both use acres planted as an explanatory variable which results in these equations having negatively correlated errors that tend to offset each other in production forecasts. Therefore, even though the acres-planted parameter has a weak t-statistic, it is kept in the yield relationship. The yield equation has a relatively low coefficient of determination (0.75), but the 5-percent coefficient of variation indicates that yield estimates are quite good.

Crushings. Crush forms the basis for important linkages between the soybean market and its product markets. Two different crush series are maintained by the model. Crush used in the soybean balance sheet is on the uneven-quarter basis, while crush used for the product markets is on the even-quarter basis. Soybean crush on the even-quarter basis is derived from the soybean meal market using the identity of crush equaling production divided by yields. Soybean crush on an uneven-quarter basis is then derived by adjusting even-quarter crush.

Total Use and Stocks. Total soybean use is derived by adding uneven-quarter exports and seed, feed, and residual to uneven-quarter crush. Total soybean stocks then clear the market as a residual, subtracting uneven-quarter use from total supply. This results in stocks being estimated for dates corresponding to the survey dates used for historical data.

Price. The soybean price equation is estimated using a hyperbolic functional form to relate prices to ending stocks. Stocks are measured relative to a "scale of activity" indicator in the soybean sector, represented by use. This is necessary because of industry growth over the last 15 years. Further, separate hyperbolae are estimated for each quarter to reflect the different importance of stocks through the marketing year. Plotting the resulting hyperbolic functions relating prices to the stocks-to-use ratio gives four negatively sloped curves, convex to the origin, with the hyperbolae closer to the origin representing quarters later in the marketing year (*50, 51*). A separate autoregressive parameter is also estimated for each quarter in the soybean price equation. Other important variables in this equation are the prices of soybean meal and soybean oil to reflect derived demand factors and the personal consumption deflator to account for inflation.

Meal Yields. Soybean meal crushing yields are extremely stable and could have been left exogenous. However, validation statistics indicate a superior performance of this equation compared with the most likely alternative (naive "no-change" model) if yields were not endogenized. Soybean meal yields are related to the level of crush and trend. Even though the coefficient of determination is low, the coefficient of variation is extremely low. This implies that equation estimates of soybean meal crushing yields are very good even though the small amount of variation present in that series is poorly explained.

Meal Production and Supplies. The soybean meal production equation is determined by domestic meal use, meal exports, and seasonal dummy variables. Accounting for roughly 75 percent of total use, domestic meal demand is the most important factor determining the level of production. With a coefficient of determination of 0.998 and a coefficient of variation of 1 percent, the model reflects the close correspondence and rapid adjustment of production to meal demand. Beginning stocks and supplies are determined by identities.

Domestic Meal Use. The domestic soybean meal use equation determines the derived demand for soybean crushings. It is also the major demand side link to the livestock and corn sectors and, consequently, is possibly the single most important equation in the soybean sector. The structure of quarterly demand is "cobweb" in nature: livestock feeders cannot respond immediately to price changes, so prices of meal, corn, and livestock products are lagged one quarter. The coefficient for soybean meal price in the previous quarter implies an elasticity of -0.33, which is in the expected range based on previous research on demand for livestock feed. The implied cross-price elasticity between meal use and lagged corn price is -0.18. A negative cross-price elasticity suggests poor substitutability or possibly complementarity between the corresponding factors of production and is consistent with the relationship between these two factors found in the corn feed demand equation.

The longrun effect of sows farrowing on soybean meal use is found by adding the coefficients of the two lagged variables. This implies a longrun elasticity of soybean meal demand to sows farrowing of 0.32: a 1-percent increase in sows farrowing will lead to a 0.32-percent total increase in meal use over the following two quarters. Using an average number of pigs saved per litter of 7.17, and adjusting the result to represent total U.S. farrowings, the sows farrowing coefficients imply about 115 pounds of soybean meal fed per hog, from farrow to finish. This compares favorably with the typical feeding operation's rate of about 130 pounds of high-protein feed, not all of which is necessarily soybean meal.

The livestock price index in the previous quarter represents expected returns to feeding and indicates a strong relationship between expected product price and feed demand. Hay price is included in the meal demand equation to represent the costs of alternatives to soybean meal feeding. In the short run, decision-makers considering the placement of cattle into feedlots can respond to relative costs of feedlot and pasture feeding. The implied cross-price elasticity is 0.29. The net cattle placements coefficient in the meal demand equation implies feeding greatly in excess of typical feedlot operations feeding. It is likely the cattle placements series is collinear with, and therefore measures the effect of, other factors affecting soybean meal demand, such as environmental stress and grazing conditions.

Meal Price. In the soybean meal price equation, extreme collinearity between the soybean meal supply and the soybean meal use variables caused parameter estimates from ordinary least squares to have large variances and unexpected signs. Consequently, the soybean meal price equation was estimated with a principal components regression (*29*). This allowed parameters on some correlated variables to change sign, although the significance of several of the parameters is still low. The reported coefficient of determination of 0.88 has been calculated using (SST—SSE)/SST, where SST is the mean corrected total sum of squares of meal prices and SSE is the sum of squared errors. It compares well with the coefficient of determination of 0.92 from the ordinary least squares regression.

Oil Yields and Supply. As for soybean meal, the extremely stable soybean oil crushing yields could have been left exogenous, but they are endogenized because of implications of model validation statistics. Soybean oil yields are related to the level of crush, trend, and seasonal shifters. As with soybean meal yields, the coefficient of determination is low but so is the coefficient of variation, implying that equation estimates of yields are very good even though the small amount of variation present in that series is poorly explained. Production, beginning stocks, and supplies are determined by identities.

Domestic Oil Use. Domestic soybean oil demand has been estimated on a per capita basis, with the explanatory variables of price and disposable per capita income deflated by the personal consumption expenditures deflator. The seasonal nature of demand is represented by the inclusion of quarterly dummy variables. The income elasticity of 1.66 suggests that soybean oil is a luxury as a food, reflecting its use in food preparation in away-from-home establishments and in partially prepared foods sold for at-home eating. The own-price elasticity estimate is −0.09; soybean oil prices account for a small portion of the prices of the retail products, so demand responds little to changes in soybean oil prices.

Oil Price. As in other price equations, the soybean oil price equation includes a one-quarter lag of oil price. Soybean oil supply, soybean oil use, July temperature, and a dummy variable covering the 1973/74 soybean marketing year are also included. The July temperature coefficient implies a price flexibility of 0.14. This is consistent with similar estimates found for corn that measure the marginal price impacts of preharvest information before that information is realized in the following crop year.

Cattle Sector[5]

Eight annual equations provide inventory information which, combined with two quarterly liquidation equations, represent cow/calf operations and set breeding herd constraints on the cattle sector.

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[5]The authors thank Richard Stillman for his collaboration on the formulation of the general framework for the livestock sector models. Much of the livestock sector presented here uses the structure of a livestock model from Stillman (*34*). Some parts of that framework, however, have been restructured here to meet the overall model design of the quarterly agriculture forecasting model. Also, the estimation periods differ from those used by Stillman.

Cow Inventories. The cow inventory equation is an identity that links the breeding herd for a given year to replacement and liquidation decisions made in the previous year. The coefficient of 0.98 on the previous year inventory reflects the assumption of a 2-percent death loss.

Steer and Heifer Inventories. The inventory equations for steers and heifers over 500 pounds are each functions of the previous year's calf crop and the previous year's deflated feeder steer prices. The calf crop variable constrains these inventories by linking them to breeding herd decisions in the previous year. Theoretically, the calf crop coefficient in each equation is bounded from above by 0.50, but estimates are lower due to calf slaughter and deaths, breeding herd retentions, and late-born calves that have not reached 500 pounds by January 1. The annual feeder steer price variables reflect expected returns to producing feeders.

Heifers Entering the Cow Herd. Additions to the breeding inventory, that is, heifers entering the cow herd, are derived by an identity using results from estimated equations for heifers kept for replacement and the proportion of those kept that actually enter the cow herd. Heifers kept for replacement are related to the size of current-year inventories, as a measure of industry scale, and to the cow slaughter rate in the previous year, representing the phase of the cattle cycle. The proportion of heifers kept that enter the cow herd is related to annual deflated feeder steer prices, deflated hay prices, and the cow inventory. The combined effects of the linear and squared real feeder steer price variables reflect the price (expected returns) incentive to producing and supplying feeder steers, so a larger real price implies a greater share of heifers kept actually entering the breeding herd. Deflated hay price, as a proxy for grazing conditions, reflects production costs of feeders. The cow inventory variable represents the size of the industry.

Calf Crop and Calving Rate. The calf crop produced by the breeding herd is derived using cow inventories and an estimated equation for the calving rate. The calving rate is related to the ratio of replacement heifers kept to the cow inventory, the change in lagged annual deflated feeder steer prices, and deflated hay prices. The first variable reflects the formula used for calculating the reported calving rate. Defined as the number of calves born divided by the January 1 cow inventory, the numerator includes calves born to heifers that were not in the January 1 cow inventory, but the denominator does not include those heifers. Thus, the higher the ratio of heifers to cows, the higher the statistically reported calving rate, even though heifers have a lower biological calving rate than that of cows. The feeder steer price variables and the deflated hay price variable again represent expected returns and costs of producing feeders.

Cow and Bull Slaughter. Quarterly cow slaughter is related to feeder steer prices and the size of cow inventories. The first again represents expected returns of producing feeders; as the three-quarter moving average of feeder steer prices falls, breeding herd liquidation rises. Cow inventories reflect the industry scale, and the interaction of inventories with quarterly dummy variables reflects the seasonality of liquidation. The largest cow slaughter occurs in the fourth quarter prior to winter when the costs of maintaining the herd are largest. Conversely, the smallest cow slaughter occurs in the second quarter prior to summer when grazing opportunities reduce feeding costs.

Bull slaughter primarily depends on the same herd liquidation decisions that affect cow slaughter, so cow slaughter is included to summarize that effect. Interaction terms of cow slaughter with quarterly dummy variables adjust for different seasonality in bull slaughter and reflect the ability to implement liquidation decisions sooner after breeding with bulls than with cows.

Net Placements. Net placements of cattle on feed provide a link between cow/calf operators and feeders. It is a function of the expected returns of feeding relative to the feed costs of production (moving average of fed steer prices divided by the lagged price of corn), the cost of feeder cattle, and the size of the breeding herd through seasonal interaction terms with the calf crop. Higher expected returns lead to greater placements while higher costs of production (feeders or feed) lead to lower placements. Placements in the first three calendar quarters are primarily drawn from the previous year's calf crop, while fourth-quarter placements are more likely to be drawn from the current year's calf crop. The seasonal pattern indicated shows that placements are smallest in the first quarter as the previous year's calf crop has not reached placement weight. Placements become successively larger in each of the following quarters, becoming the largest in the fourth quarter when alternative feeding options are reduced.

Cattle on Feed and Fed Cattle Marketings. Cattle on feed are then derived as an identity. Fed cattle marketings are a function of cattle on feed inventories plus placements with interactions with quarterly dummy variables allowing for seasonality. The seasonal pattern indicated is consistent with the seasonality in quarterly placements and feeding schedules.

Fed Steer and Heifer Slaughter. Cattle on feed inventories, placements, and marketings are 13-State data and must be transformed to reflect feedlot activity in the entire country. The parameter estimates represent expansion factors from marketings to slaughter, with seasonal effects again allowed through interaction terms. The seasonal slope shifters imply that fed steer and heifer slaughter outside the 13 survey States has greater seasonal distribution in the second and third quarters.

Nonfed Steer and Heifer Slaughter. Nonfed steer and heifer slaughter is inversely related to the factors that affect feedlot placement decisions and the level of fed slaughter. The more attractive feeding is—expected fed steer price high and corn price low—and the higher the level of fed slaughter, the smaller is nonfed slaughter. Also, similar to placement animals, nonfed slaughter is constrained by the annual calf crop in the previous year for the first three calendar quarters and by the annual calf crop in the current year for the fourth quarter.

Commercial Slaughter. Total commercial steer and heifer slaughter and commercial cattle slaughter are each derived by an identity.

Average Dressed Weight and Beef Supply. The moving average of fed steer prices is included in the equation for average dressed weight to represent expected returns to feeding to heavier weights. The ratio of steer and heifer slaughter to cow slaughter adjusts for the weight differences between those animal groups.

A series of beef supply identities gives commercial beef production, total production, beginning cold storage stocks, and total beef supplies.

Stocks. A cold storage beef stocks equation is estimated rather than a beef consumption equation to reflect the method used to collect and report the historical series where consumption is derived as a residual. Ending stocks is a function of beginning stocks and imports, with separate quarterly coefficients allowed for each to reflect seasonality in stockholding patterns and stocks composition. The parameters on beginning stocks reflect the average duration of stocks being held. Imports represent the major source of additions to stocks.

Consumption. The procedure used for deriving the historical data is used in the model to derive, in identities, civilian consumption and per capita consumption on both carcass and retail weight bases.

Prices. Four price equations complete the cattle sector. Prices for fed steers and farm-level cattle are functions of fed and nonfed cattle slaughter, representing supplies, and income variables, representing derived demand factors. Diet habits tend to make demand slow in responding to income changes. This is especially true for beef which has been the traditional favorite meat in consumption, so an eight-quarter moving average of income is used. Further, the log of this moving average income variable is used to reflect diminishing marginal utility of consumption. Additionally, meat demand was hypothesized to respond to both levels and changes in income, so the change in the log of the moving average of income is also included. Prices for feeder steers and farm-level calves are then related to fed steer prices to represent the demand for feeders, the previous year's calf crop to represent potential supplies, and lagged corn prices to represent production costs.

Hog Sector

The hog slaughter block used in the hog sector is simpler than that used for the cattle sector, but it is sufficient to support the pork supply and utilization equations. Only six equations are needed to derive total hog slaughter due to two main differences between the hog and cattle industries. First, the biological production lags are shorter for hogs than for cattle. Second, the hog market structure is much more vertically integrated with a large percentage of farrow-to-finish operations, while in the cattle industry, there is a greater dichotomy between breeders and feeders.

Sows Farrowing and Pig Crop. Sows farrowing is a function of expected returns to hog production represented by a three-quarter moving weighted average of the seven-market hog price. The coefficient implies an elasticity of 0.44. Lagged prices for corn, the major hog feed, represent expected costs of production, with the coefficient indicating a relatively low elasticity of −0.11. Lagged sows farrowing variables are used to represent relatively stable seasonality in farrowings from year to year and to capture longer run cyclical production decisions. The pig crop is derived by an identity.

Barrow and Gilt Slaughter. Barrow and gilt slaughter then draws on the pig crops in the two previous quarters, representing the 5- to 6-month farrow-to-finish production process. The seasonal dummy variables suggest that as weight gains slow in the fall and winter quarters, marketings are delayed somewhat relative to other times in the year, and are pushed into the winter and spring quarters.

Sow Slaughter and Boar Slaughter. Sow slaughter and boar slaughter represent breeding herd liquidation decisions based on biological lags, expected returns and costs, and seasonality. Sows farrowing in the previous quarter is in the sow slaughter equation to represent the sows available for slaughter after the newborn pigs are weaned. Expected returns are represented by the moving weighted average of hog prices while corn price represents the expected costs of production. The seasonal dummy variables indicate that sow slaughter is largest in the October-December quarter prior to winter when costs of maintaining the breeding herd rise.

Boar slaughter is related to the same factors that affect sow slaughter, so sow slaughter is included to summarize those factors. The positive coefficient on the interaction term of sow slaughter with a second quarter dummy variable reflects the ability to implement herd liquidation decisions sooner after breeding with boars than with sows and the incentive to slaughter heavy boars prior to the summer months when breeding efficiency is reduced. The moving weighted average of hog prices represents an additional expected returns affect in the boar slaughter decision beyond that already represented indirectly by the sow slaughter variable.

Total Hog Slaughter. Total hog slaughter is the sum of barrow and gilt slaughter, sow slaughter, and boar slaughter.

Pork Production and Supply. A structure similar to that used for the beef supply and use equations is used here for pork. A series of pork supply identities give commercial production, total production, beginning cold storage stocks, and total pork supplies.

Stocks. The equation for ending cold storage pork stocks is a function of beginning stocks and production. Similar to the beef stocks equation, separate quarterly coefficients are allowed for each independent variable to reflect seasonality in stockholding patterns and stocks composition. The beginning stocks parameters again reflect the average duration of stocks being held, while pork production represents potential additions to stocks.

Consumption. Civilian consumption and per capita consumption of pork on both carcass and retail weight bases are derived in identities.

Prices. Two price equations complete the hog sector. The average hog price for seven major markets is a function of pork production representing supplies, beef production representing competing meat supplies, and income variables representing derived demand factors. As in the cattle sector, the log of an eight-quarter moving average of income and the change of the log of the moving average of income are included to represent diet habits, diminishing marginal utility of consumption, and the hypothesis that both levels and changes in incomes affect demand. Prices for farm-level hogs are then related to the seven-market hog price to represent the derived demand for hogs.

Poultry Sector

The poultry sector in the model has a smaller block for breeding animals than was used in the cattle sector. Two broiler breeding flock equations are used as the basis for deriving broiler production estimates needed to support the chicken supply and use equations. Turkey production is estimated with no explicit breeding flock constraints. This structure reflects the shorter biological production lags and the high degree of vertical integration in the broiler and turkey industries.

Broiler Breeding Stock. Broiler pullets placed in hatchery supply flocks represent additions to the capital stock from which slaughter broilers are drawn. The four-quarter lag of placements is used because of the stable seasonality of placements from year to year. Expected feeding costs are represented by the two-quarter lag of a constructed feed cost variable, derived using a 70-percent corn and a 30-percent soybean meal feed ration. Expected returns are represented by the two-quarter lag of broiler prices. Time trend indicates the long-term growth in the broiler industry. The second quarter dummy variable reflects seasonally higher placements in the spring following the cold weather months when breeding flock maintenance costs are highest.

Broiler Hatch. Broilers hatched draw from the hatchery supply flock, represented by a weighted moving sum of placements two through four quarters earlier. The weights used are from Chavas and Johnson (6) and reflect declining productivity through the laying cycle for broiler-type chickens. The estimated coefficient implies about 46 eggs are hatched per broiler-type hen in the hatchery supply flock over the laying cycle: 19 eggs two quarters after placement, 15 eggs in the following quarter, and 12 eggs four quarters after placement. Also included in the broiler hatch equation are lagged broiler prices and lagged feed prices to represent expected returns and expected production costs, respectively. Quarterly dummy variables indicate that hatch is largest in the second quarter and smallest in the fourth quarter. Trend again indicates the long-term growth in the broiler industry.

Broiler Production and Chicken Supplies. Broiler production is related to the one-quarter lag of broiler hatch to reflect the time needed to bring the birds to market weight. As before, expected returns and costs are represented by the one-quarter lags of prices for broilers and feed. Broiler industry growth is indicated by the positive time trend coefficient. Beginning cold storage stocks are derived by an identity and added to production to give total chicken supplies.

Chicken Stocks. The equation for ending chicken stocks in cold storage is a function of beginning stocks and broiler production. Separate quarterly coefficients are allowed for beginning stocks whose parameters reflect the average duration of stocks being held. Broiler production represents potential additions to stocks.

Chicken Consumption. Similar to beef and pork, civilian chicken consumption and per capita consumption are derived in identities following the procedure used to derive the historical data.

Broiler Prices. Two price equations complete the chicken part of the poultry sector. The nine-city broiler price is a function of broiler production representing supplies, beef and pork production representing competing meat supplies, and income variables representing derived demand factors. As in the cattle sector, the log of a moving average income variable and the change of the log of the moving average of income are included to represent habits in diets, diminishing marginal utility of consumption, and the hypothesis that both levels and changes in income affect demand. Here, however, a shorter, four-quarter moving average is used because the role of beef as the traditional favorite meat implies quicker adjustments in chicken consumption habits. Farm-level broiler prices are then related to nine-city broiler prices to represent derived demand, with a positive trend implying smaller margins that have resulted from economies of scale.

Turkey Production and Supplies. Turkey production is estimated directly without any explicit link to a supporting set of breeding flock equations. Turkey production is related to the two-quarter lags of turkey prices and corn prices to reflect expected returns and feeding costs. The seasonal dummy variables indicate higher production in the second half of the year when production is increased to meet larger holiday demand. The positive time trend coefficient indicates growth in the turkey industry. Beginning cold storage stocks are derived by an identity and added to production to give total turkey supplies.

Turkey Stocks. Similar to earlier specifications, the ending turkey stocks equation is a function of beginning stocks and turkey production. Separate quarterly coefficients are allowed for each independent variable to reflect seasonal stockholding patterns, which are especially important for turkeys. As for other meat stocks categories, the beginning stocks parameters reflect the average duration of stocks being held, while turkey production represents potential additions to stocks.

Turkey Consumption. Civilian turkey consumption and per capita consumption are derived in identities.

Turkey Price. A price equation completes the turkey part of the poultry sector. Farm-level turkey price is a function of the sum of beef, pork, and broiler production representing competing meat supplies and income variables representing derived demand factors. The log of a moving average income variable and the change of the log of the moving average of income are included to represent diet habits, diminishing marginal utility of consumption, and the hypothesis that both levels and changes in income affect demand. Similar to chicken, a four-quarter moving average income variable is used to reflect quicker adjustments in eating habits for poultry than for beef.

Prices Received by Farmers for Livestock

An aggregate measure of farm-level livestock prices is determined in an identity using fixed quantity weights derived from 1971-73 cash receipts from Thorp (*36*). The prices for eggs and milk, needed to fully represent the index of prices received by farmers for livestock, are exogenous to the model.

Model Validation

Evaluation of the model was conducted for two major purposes. First, dynamic properties were investigated to assure stability of the model. Second, validation statistics were generated from simulations designed to test the model on the basis of its intended use as a three- to six-quarter ahead forecasting tool.

In accord with the first purpose, a dynamic simulation of the model from 1975 through 1981 was performed using actual exogenous data throughout. Using the Gauss-Seidel solution method, the model converged quickly in most quarters with no quarter requiring more than 20 iterations. Validation statistics generated from this simulation (not presented here) show reasonably good model performance. A series of additional simulations over the 1975 through 1981 interval was also performed: selected exogenous variables were impacted in one quarter, one year, or throughout the entire simulation interval, with separate simulations run for each. The model again converged quickly in all simulations with no quarter requiring more than 21 iterations. These simulations suggest that stability concerns are not a problem with the model.

In order to test the model on the basis of its intended use as a three- to six-quarter ahead forecasting tool, separate dynamic model simulations were performed for each within-sample year from 1975 through 1981 (limited to this interval by data availability). This gave 28 model predictions for quarterly variables and 7 model predictions for annual variables. Two beyond-sample simulations were performed over the eight quarters and the two annual observations of 1982 and 1983. Actual exogenous data were used throughout all simulations. Validation statistics, based on these dynamic simulations of the model, are presented in table 1 and form the basis of a quantitative evaluation.

Table 1 shows summary validation statistics for each dependent variable. Relative mean absolute errors (RMAE), Theil inequality coefficients, and the relative number of turning point errors (RTPE) are presented. RMAE equals the mean absolute error (MAE) expressed as a percent of the mean of the dependent variable ($\bar{y}$). That is, RMAE = (MAE/$\bar{y}$) 100. The Theil inequality coefficient equals

$$[\Sigma\ [(p_t - a_{t-k}) - (a_t - a_{t-k})]^2 / \Sigma (a_t - a_{t-k})^2\ ]^{0.5}$$

where p_t and a_t are the predicted and actual values of variables in time period t and summations are taken over all simulation periods. For annual series, k=1 to indicate the previous annual value. For quarterly series, k=4 to indicate the four-quarter-ago value. For annual series, when t=1, a_0 is set equal to the last presimulation value of the endogenous variable. Similarly, for quarterly series, when $t \leq 4$, actual presimulation values of the endogenous variables are used for a_{t-4}. A Theil inequality coefficient less than 1 implies superior simulation performance relative to a "naive" forecast of no change from one year earlier (annual series) or four quarters earlier (quarterly series). The RTPEs are the number of turning point errors expressed as a percent of the total number of simulation observations. A turning point error occurs when

$$(p_t - a_{t-k})(a_t - a_{t-k}) < 0$$

with k=1 for annual series to indicate year-to-year changes and k=4 for quarterly series to indicate changes from four quarters earlier. As for the Theil inequality coefficients, actual presimulation values of endogenous variables are used when needed (annual series, when t=1; quarterly series, when $t \leq 4$).

Table 1—Quarterly agriculture forecasting model validation statistics[1]

Dependent variable	Relative mean absolute error (percent)[2]		Theil inequality coefficient[3]		Relative turning point errors (percent)[4]	
	Within sample	Beyond sample	Within sample	Beyond sample	Within sample	Beyond sample
Corn:						
Annual—						
Planted acres	2.0	5.3	0.71	0.29	14	50
Harvested acres	1.5	4.6	.72	.21	43	50
Yields	1.8	20.2	.16	.99	0	50
Production	1.9	15.5	.15	.44	0	50
Quarterly—						
Beginning stocks	2.2	1.5	.17	.10	4	0
Supply	1.9	3.9	.20	.36	0	0
Feed	6.0	8.7	.57	1.28	18	25
Food and industrial	3.7	10.7	.43	1.16	11	50
Alcoholic beverages	4.8	26.5	.62	1.17	29	88
Seed	2.6	15.5	.87	.79	0	38
Total use	3.7	5.2	.38	1.08	18	25
Free stocks	4.6	15.6	.30	.55	4	25
Ending stocks	3.6	6.9	.25	.38	4	0
Corn price, farm	5.3	19.9	.42	1.01	4	38
Wheat:						
Annual—						
Planted acres	4.7	17.4	.77	2.03	0	50
Harvested acres	2.1	3.4	.22	.26	0	0
Yields	1.8	3.1	.47	.42	29	50
Production	3.8	6.2	.33	.70	14	0
Quarterly—						
Beginning stocks	1.4	1.0	.13	.18	7	0
Supply	1.9	2.2	.22	.43	4	13
Feed[5]	121.1	49.4	1.04	.90	18	13
Food	2.2	2.1	.60	.99	32	38
Seed	7.7	20.8	.76	1.85	4	25
Total use	6.3	5.6	.66	.61	11	13
Free stocks	3.1	3.8	.20	.27	0	0
Ending stocks	2.2	1.6	.19	.22	11	0
Wheat price, farm	8.5	6.8	.47	1.05	18	38
Soybeans:						
Annual—						
Planted acres	4.4	8.3	.66	1.29	14	50
Harvested acres	4.4	8.3	.64	1.28	14	50
Yields	4.4	9.6	.40	.65	0	50
Production	6.5	17.8	.39	.85	0	0
Quarterly—						
Supply	2.8	7.0	.31	.85	4	13
Crush, even quarters	4.4	9.6	.37	1.08	7	25
Crush, uneven quarters	3.8	9.5	.37	1.20	4	38
Total use	2.1	4.9	.20	.58	0	13
Ending stocks	4.6	11.5	.36	.85	4	13
Soybean price, farm	9.6	18.0	.58	.89	21	50

See footnotes at end of table.

Continued—

Table 1—Quarterly agriculture forecasting model validation statistics[1]—Continued

Dependent variable	Relative mean absolute error (percent)[2]		Theil inequality coefficient[3]		Relative turning point errors (percent)[4]	
	Within sample	Beyond sample	Within sample	Beyond sample	Within sample	Beyond sample
Soybean meal:						
Quarterly—						
Yields	0.6	0.2	0.79	0.52	29	0
Production	4.3	9.6	.37	1.07	7	25
Supply	3.9	9.3	.38	1.15	7	38
Domestic use	5.7	13.0	.55	1.32	14	38
Total use	4.2	9.4	.37	1.24	4	25
Ending stocks	16.2	26.9	.64	.72	18	25
Soybean meal price	10.4	15.1	.61	1.15	11	63
Soybean oil:						
Quarterly—						
Yields	1.7	2.6	.63	.83	18	0
Production	4.2	11.3	.35	1.30	4	38
Supply	3.4	19.2	.32	3.55	4	63
Domestic use	4.0	3.6	.42	1.13	21	13
Total use	3.3	3.0	.33	.67	7	0
Ending stocks	10.3	49.7	.32	2.45	14	63
Soybean oil price	11.4	15.8	.48	.71	18	25
Cattle:						
Annual—						
Cow inventory[6]	2.0	3.6	.62	2.17	0	100
Steers on farms[6]	3.6	2.9	1.55	1.02	14	50
Heifers on farms[6]	3.5	8.6	1.21	4.10	43	50
Heifers kept for cow replacement	1.5	4.3	.21	.96	0	0
Proportion of heifers kept that enter the cow herd	2.5	14.1	.28	.88	0	50
Heifers entering the cow herd	3.5	10.6	.31	.97	0	50
Annual calving rate	.7	2.5	.21	1.32	0	50
Annual calf crop	.7	2.5	.21	3.60	0	100
Quarterly—						
Cow slaughter	12.7	14.3	.63	1.98	11	75
Bull slaughter	10.1	11.7	.65	2.16	18	63
Net placements	6.0	10.7	.63	1.27	29	25
Cattle on feed	3.8	8.2	.34	1.79	29	13
Fed cattle marketed	3.7	4.4	.46	1.32	14	0
Fed steer and heifer slaughter	3.9	4.7	.46	1.15	14	0
Nonfed steer and heifer slaughter	19.8	23.2	.52	.82	7	38
Total steer and heifer slaughter	2.7	2.3	.55	1.46	21	25
Commercial cattle slaughter	4.1	2.2	.57	1.02	11	38
Average dressed weight	1.8	1.7	.54	1.21	39	25
Beef production, commercial	3.3	1.6	.62	.60	14	13
Beef production, total	3.3	1.5	.62	.59	14	13
Beginning beef stocks	7.7	9.3	.44	.39	14	0
Total beef supply	2.9	1.2	.63	.42	7	13
Ending beef stocks	12.0	11.1	.60	.44	21	0
Civilian beef consumption, carcass weight	2.9	1.2	.62	.50	14	0
Civilian per capita beef consumption, carcass weight	2.9	1.2	.60	.65	21	25
Civilian per capita beef consumption, retail weight	2.9	1.1	.60	.64	21	25
Fed steer price	7.3	4.4	.52	1.29	18	50
Cattle price, farm	7.7	11.8	.44	3.78	25	75
Calf price, farm	11.7	25.2	.46	3.10	7	63
Feeder steer price	9.2	18.7	.46	3.01	14	50

See footnotes at end of table.

Continued—

Table 1—Quarterly agriculture forecasting model validation statistics[1]—Continued

Dependent variable	Relative mean absolute error (percent)[2]		Theil inequality coefficient[3]		Relative turning point errors (percent)[4]	
	Within sample	Beyond sample	Within sample	Beyond sample	Within sample	Beyond sample
Hogs:						
Quarterly—						
Sows farrowing	3.3	14.8	0.34	1.52	14	38
Pig crop	3.3	14.8	.36	1.40	11	38
Barrow and gilt slaughter	3.7	7.0	.36	.76	14	13
Sow slaughter	7.5	15.1	.36	.73	18	25
Boar slaughter	6.4	19.7	.39	1.03	18	38
Hog slaughter	3.6	6.3	.34	.68	11	13
Pork production, commercial	3.6	6.4	.34	.71	11	13
Pork production, total	3.6	6.3	.33	.70	11	13
Beginning pork stocks	5.6	6.2	.46	.35	7	13
Total pork supply	3.2	5.9	.32	.67	11	13
Ending pork stocks	8.6	10.4	.58	.55	11	25
Civilian pork consumption, carcass weight	3.5	6.1	.33	.74	7	13
Civilian per capita pork consumption, carcass weight	3.5	6.0	.32	.72	14	13
Civilian per capita pork consumption, retail weight	3.5	6.0	.34	.78	11	13
Barrow and gilt price	8.9	11.1	.41	.61	14	0
Hog price, farm	9.0	11.1	.41	.60	14	13
Poultry:						
Quarterly—						
Broiler pullets placed in hatchery supply flocks	4.9	13.8	.60	2.69	18	75
Broiler hatch	1.5	4.3	.29	3.11	7	63
Broiler production	1.7	3.0	.30	1.51	11	25
Beginning stocks, young chickens	10.3	15.1	.43	.67	7	13
Total chicken supply	1.7	3.1	.31	1.65	18	25
Ending stocks, young chickens	16.0	28.3	.57	1.01	14	38
Civilian consumption, young chickens	1.7	3.1	.33	1.01	11	13
Civilian per capita consumption, young chickens	1.7	3.1	.36	1.22	7	25
Broiler price, nine-city	6.1	12.8	.51	1.26	7	75
Broiler price, farm	7.3	13.4	.50	1.26	4	88
Turkey production	5.5	12.8	.80	2.48	21	63
Beginning stocks, turkeys	9.2	10.6	.64	1.06	14	25
Total turkey supply	5.9	11.6	.76	2.10	18	63
Ending stocks, turkeys	12.2	19.6	.71	1.48	21	50
Civilian consumption, turkeys	5.6	10.7	.81	1.55	25	75
Civilian per capita consumption, turkeys	5.6	10.6	.85	1.70	21	63
Turkey price, farm	7.2	11.5	.61	1.41	11	63
Aggregate livestock sector:						
Quarterly—						
Prices received by farmers for livestock	4.6	4.6	.42	1.53	7	25

[1]Based on dynamic simulations of the quarterly agriculture forecasting model with regard to the endogenous variables, using actual exogenous data throughout. Within-sample simulations: 1975-1981; beyond-sample simulations: 1982-1983.

[2]RMAE equals 100 times the mean absolute error relative to the mean of the dependent variable—$(MAE/\bar{y})100$.

[3]The Theil inequality coefficient equals $[\Sigma[(p_t - a_{t-k}) - (a_t - a_{t-k})]^2/\Sigma(a_t - a_{t-k})^2]^{0.5}$, where p_t and a_t are the predicted and actual values of variables in time period t. For annual series, k=1 to indicate the previous annual value. For quarterly series, k=4 to indicate the four-quarter-ago value. For annual series, when t=1, a_0 is set equal to the last presimulation value of the endogenous variable. Similarly, for quarterly series, when $t \leq 4$, actual presimulation values of the endogenous variables are used. A Theil inequality coefficient less than 1 implies superior simulation performance relative to a "naive" (no-change) forecast.

[4]RTPE equals 100 times the number of turning point errors divided by the total number of simulation observations. A turning point error occurs when $(p_t - a_{t-k})(a_t - a_{t-k}) < 0$, with k=1 for annual series indicating year-to-year changes and k=4 for quarterly series indicating changes from four quarters earlier. As for the Theil inequality coefficients, actual presimulation values of endogenous variables are used when needed (annual series, when t=1; quarterly series, when $t \leq 4$).

[5]Since negative values for wheat feed use occur, the mean dependent variable is artificially low. If the denominator for the relative mean absolute error is changed to the mean of the absolute value of wheat feed use, the relative mean absolute error is 77.0 percent in the within-sample simulations and 44.0 percent in the beyond-sample simulations.

[6]January 1 inventory statistics derived for the year following each simulation.

These three summary statistics were chosen because they represent three properties desired of forecasting models: a measure of the simulation errors, a measure of how well turning points are "caught," and a comparison of the econometric model with an appropriate naive model, which here, is the simple model of no change from one year earlier (annual series) or four quarters earlier (quarterly series).

Both the Theil inequality coefficient and the turning point error analyses employ the term $(p_t - a_{t-k})$ which is the change between the current predicted level and the actual level one year or four quarters ago. Actual levels from one year or four quarters earlier were used rather than predicted levels because the model is designed to be a short-term forecasting model where, in most applications, year ago or four-quarter-ago levels will be known. This is consistent with Theil's definition of the inequality coefficient (*35*, p. 28) expanded on later (*35*, p. 48) where Theil implicitly defines the predicted change as $p_t - a^*_{t-k}$ where a^*_{t-k} is the level of a_{t-k} known at the time the forecast is made. Since here we are forecasting four quarters ahead, a_{t-k} will always be know and hence a^*_{t-k} equals a_{t-k}. Also, for quarterly series, levels from four quarters earlier were used instead of levels from one quarter earlier because of the seasonality evident in most agricultural variables.

The within-sample validation statistics demonstrate that the model's performance was quite good. Most of the within-sample RMAEs are less than 10 percent, only three Theil inequality coefficients exceed 1, and the within-sample RTPEs are low for most variables.

Most variables perform well for at least two of the three forecasting properties summarized by the statistics presented here. To illustrate, with the exception of feed use of wheat, ending beef stocks, and ending turkey stocks, all other variables with RMAEs exceeding 10 percent have low Theil inequality coefficients and RTPEs below 20 percent. The onfarm steer inventory category, which has a Theil inequality coefficient of 1.55, has a low RTPE of 14 percent and a low RMAE of 3.6 percent. Further, except for onfarm heifer inventories, all other variables with RTPEs exceeding 25 percent have Theil inequality coefficients below 1 and reasonably low RMAEs.

Feed use of corn, domestic use of soybean meal, all prices, the index of prices received by farmers for livestock, net placements of cattle on feed, cattle on feed, and sows farrowing all perform very well in the within-sample simulations. This is particularly important because these variables provide most of the critical links between the crop sector and the livestock sector. Price performance is quite good, especially since prices tend to be more volatile than the major supply and use categories. Although prices for calves, soybean meal, and soybean oil have within sample RMAEs between 10 and 12 percent, all other prices have lower RMAEs. The largest within-sample Theil inequality coefficient for a price category is 0.61, and no price series has a within sample RTPE exceeding 25 percent.

Finally, most categories with RMAEs exceeding 10 percent are categories that are relatively small in magnitude and, therefore, less important in determining overall supply and demand for each commodity. For example, nonfed steer and heifer slaughter has a 19.8-percent RMAE, but because it is a relatively small part of total steer and heifer slaughter, the latter's RMAE is only 2.7 percent. The relatively small ending stocks category for young chickens has a RMAE of 16.0 percent, yet the young chickens consumption estimates derived by using the stocks estimates have only a 1.7-percent RMAE. In the crop sector, soybean meal supply performs quite well (3.9-percent RMAE) in spite of the 16.2-percent RMAE in ending soybean meal stocks, mainly because average stocks represent only about 6 percent of total average soybean meal supply. Also, total wheat use has a RMAE of only 6.3 percent despite wheat feed use having a RMAE of 121.1 percent, partly because average feed use accounts for only about 6 percent of average total wheat use.

The poor performance of the wheat feed use category largely reflects the residual derivation of its historical values, so it includes feed use plus sampling and measurement errors from all other supply, use, and stocks categories. Further, because wheat feed use is relatively small, the residual derivation of this series results in negative values occurring for wheat feed use in some quarters. Consequently, the mean dependent variable used in the derivation of RMAE is artificially low. If the denominator for the relative mean absolute error is changed to the mean of the absolute value of wheat feed use, the resulting relative mean absolute error is 77.0 percent in the within-sample simulations.

The beyond-sample validation statistics are poorer, indicating that 1982 and 1983 were difficult to forecast.

Many RMAEs are large, many Theil inequality coefficients exceed 1, and many RTPEs are 50 percent or larger. However, the major aggregates—supply, total use (crops), and consumption (livestock)—perform reasonably well.

Many of the errors in the 1982 and 1983 simulations are a consequence of a few unusual circumstances. In 1982, livestock producers did not respond to favorable feed prices because high interest rates and weak consumer demand put them in poor cash flow positions. As a result, the model underestimated 1982 breeding herd liquidation which, in turn, caused simulation errors in the crop sector of the model where feed use was overestimated. Some of these effects carried over into 1983 as well. Additionally, the effects of the 1983 drought on yields and production of corn and soybeans were underestimated by the model, adding to the 1983 simulation errors. Consequently, the poor beyond-sample validation statistics may simply reflect that 1982 and 1983 were years when the agriculture sector did not perform "as usual."

Additional Equations

Often when constructing large-scale econometric models, individual equations which have many desired structural properties and which perform well in a single equation framework are not used. This usually is because the equation performed unsatisfactorily when simulated in a multiequation framework and requires either a respecification of the equation or a more-involved restructuring of parts of the model. Nonetheless, these equations may be useful for certain applications which do not require full model simulations.

In the corn and wheat subsector models, this occurred for stocks and price equations. Appendix D presents corn and wheat equations for changes in stocks under CCC loan, for changes in stocks that are privately held, and for prices. The stocks equations are not part of the quarterly agriculture forecasting model because of the model structure being used for crops where stocks categories clear the market. The price equations are not part of the quarterly agriculture forecasting model because of problems encountered in model simulations.

Stocks Equations for Corn and Wheat

The stocks equations are specified in first-difference form and are based largely on a framework for an annual model of Miller, Meyers, and Lancaster (*31*) which was extended to a quarterly framework by Golden and Burman (*11*). Although their models were estimated for CCC stocks only, the theoretical framework employed is generally applicable to other stocks categories.

Changes in Corn Stocks Under CCC Loan. In the corn equation for the change in stocks under CCC loan, production enters in the harvest (fourth) quarter when placement of corn under CCC loan is largest. Current prices and expectations of future prices (assumed to be a moving average of lagged prices) affect loan activity in opposite directions. Higher current prices cause decreased placements or increased redemptions, while higher expected prices cause increased placements or decreased redemptions. The implied elasticities, calculated at variable means (using the level of stocks), are -0.86 for current price and 0.83 for expected price. Acting together, if prices have been falling recently, then expected prices will exceed current prices and more CCC loans will be held. Conversely, if prices have been rising recently, then current prices will exceed expected prices and fewer CCC loans will be held. The loan rate is multiplied by the sum of the fourth- and first-quarter dummy variables (D4 + D1). This follows Golden and Burman's procedure for handling CCC loan placements which typically occur in the first two quarters of the marketing year. Additionally, the three-quarter lag of this variable is included, representing the removal of stocks under CCC loans which have reached maturity.

The term COPLF·(D4 + D1)·DFORD·DFORE in the CCC loan equation for corn represents stocks that go directly into the farmer-owned reserve (FOR) after harvest. The incentive to do this is related to the FOR loan rate (COPLF), which is restricted so that FOR placements displace CCC placements only in the fourth and first quarters [(D4 + D1) = 1], only when direct FOR placements are allowed (DFORD = 1), and only after the FOR existed (DFORE = 1). The next term in the CCC loan equation for corn is the three-quarter lag of the previous term. This represents stocks which are not removed from CCC after the 9-month maturity period because they were not placed under CCC loan; instead they were placed directly into the FOR three quarters earlier. It also represents stocks which may have been temporarily placed under CCC loan but were moved to the FOR in the interim. Consequently, the coefficient of this term exceeds the absolute value of the coefficient of the previous term.

Changes in Privately Held Corn Stocks. The equation for changes in privately held corn stocks also has production entering in the fourth quarter when harvest occurs and stocks are replenished. Lagged privately held corn stocks affect changes in current stocks inversely—the larger the beginning stocks, the larger the removals or the smaller the net additions. Higher current prices cause more stocks to be removed or less to be added. The relatively low own-price elasticity of −0.08, again calculated using stock levels, is consistent with the disequilibrium hypothesis—a portion of privately held stocks is not explicitly demanded in a quarterly framework, so these stocks clear the market. The FOR loan rate is multiplied by the sum of the fourth- and first-quarter dummy variables (D4 + D1), representing the incentive to place the crop under loan during the heaviest placement quarters. In contrast to the CCC stocks equation, no interaction term with DFORD is needed here because crop placements under CCC loan or directly into the FOR both represent displacements from privately held stock positions.

Changes in Wheat Stocks Under CCC Loan. Similar to corn, the equation for changes in CCC wheat stocks includes production in the harvest quarter, current and expected prices, loan rate in the harvest and following quarters, and the three-quarter lag of the loan rate in the harvest and following quarters. The elasticities with respect to current and expected prices are −0.45 and 0.38, respectively. Similar to the privately held corn stocks equation, lagged ending CCC wheat stocks are included here. Also, a measure of interest rate subsidy, proxied by the difference between the 3-month Treasury bill rate and the CCC interest rate for wheat stocks, represents the incentive for using CCC placements for loans to improve liquidity for meeting cash flow obligations. Exports affect loan activity as redemptions rise or placements decline in order to support export demand.

Changes in Privately Held Wheat Stocks. Again similar to corn, the equation for changes in privately held wheat stocks includes production in the harvest quarter and lagged stocks. The higher the expected price, the stronger the incentive to hold stocks. The relatively small elasticity with respect to expected price of 0.13 is again consistent with the disequilibrium hypothesis where this category includes some stocks that are not explicitly demanded in a quarterly framework, resulting instead from shortrun supply/demand imbalances. The 3-month Treasury bill interest rate represents the cost of holding stocks.

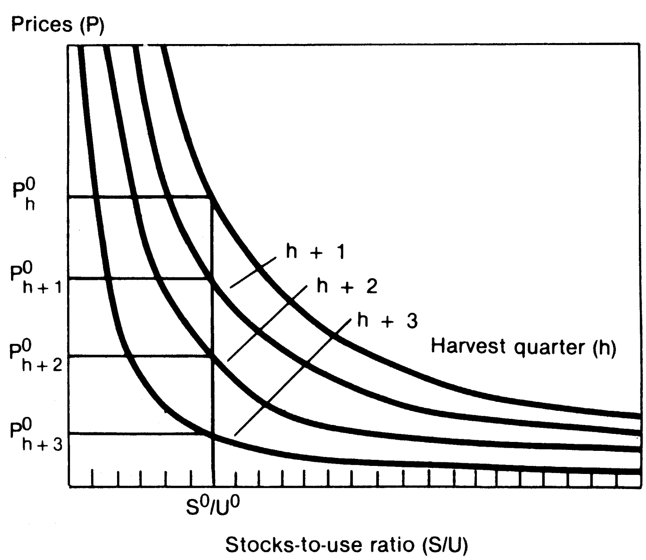
Alternative Price Equations for Corn and Wheat

The additional price equations for corn and wheat use a hyperbolic functional form to relate prices to stocks. Higher ending stocks in any particular quarter result in lower farm-level prices. However, the effects of stocks on prices differ through the marketing year, largely reflecting the annual nature of corn and wheat production. Large levels of stocks are necessary early in the marketing year to meet demand until the next harvest. As the marketing year progresses and the next harvest approaches, lower stocks are sufficient to meet use requirements. Consequently, a given level of stocks later in a marketing year results in lower prices than the same level of stocks earlier in the marketing year. To represent the different effects of stocks through the year, a separate hyperbola is estimated for each quarter. This gives a family of four hyperbolic curves (fig. 9).

For both additional price equations, a free stocks definition is used which subtracts CCC-owned stocks

Figure 9

Hyperbolic Family of Curves Relating Quarterly Prices to the Stocks-to-use Ratio



and FOR stocks from total stocks. Stocks are measured relative to the "scale of activity" in the corn and wheat industries, represented here by utilization.[6] Further, lagged price is included to reflect short-term "stickiness" of prices in a quarterly framework, largely due to the lag structures in underlying supply and demand functions. Including lagged price also allows the analysis to be conducted using nominal prices, thereby circumventing the issue of choosing an appropriate price deflator. As expected, in both additional price equations all coefficients of the inverse stocks-to-use ratios are positive.[7] The largest coefficient occurs in the harvest quarter (for corn, the term with the fourth-quarter dummy variable, D4; for wheat, the term with the third-quarter dummy variable, D3), with coefficients for successive quarters of the respective marketing years diminishing in size.

Lagged price also plays an important role. The autoregressive parameter estimates imply average price adjustment periods of about two and one-half quarters for corn and about five quarters for wheat. These estimates reflect the lags in underlying supply and demand functions that prevent instantaneous and complete market adjustments. For example, production decisions take a minimum of two quarters (corn and spring wheat) or three quarters (winter wheat) to materialize, representing the lag from plantings to harvest. Further, it may take up to an additional three quarters for supplies to respond if the production adjustment decision occurs prior to the (once-a-year) plantings quarter. Similarly, demand functions have lags which contribute to the autoregressiveness in quarterly corn and wheat prices.

[6]Utilization data have been adjusted because the corn and wheat marketing years have uneven quarters: two 3-month quarters, one 2-month quarter, and one 4-month quarter. This adjustment is done by multiplying use in the April-May quarter by 1.5 and use in the June-September quarter by 0.75. Thus, all four quarters of adjusted use data are on a prorated, 3-month equivalent basis, thereby allowing the "scale of activity" deflation of stocks to be comparable.

[7]While the hyperbolae being estimated can be expressed to show a direct relationship between prices and the stocks-to-use ratio (S/U) as shown in figure 9, the inverse of that ratio $(S/U)^{-1}$, is the appropriate explanatory variable for use in estimation. For further discussion, see (*50, 51*).

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Appendix A—Model Equations

Quarterly agriculture forecasting model equations[1]

Corn sector, annual equations

1. Corn acres planted, enters the model in the second quarter, but is solved for in the model in the first quarter

$$COAPL = 65275.92 + \underset{(1.81)}{10537.71}\ COPHR - \underset{(1.49)}{6051.21}\ WHPHR - \underset{(0.94)}{14613.61}\ CODP$$
$$- \underset{(2.24)}{51540.27}\ WHDP - \underset{(0.42)}{449.04}\ SBPFM \cdot D1 + \underset{(3.35)}{1232.80}\ (COTA + 1)$$

$R^2 = 0.938$ RMSE = 2469.43 CV = 3.31 Estimation period = 1965-1981

2. Corn acres harvested for grain, enters the model in the fourth quarter

$$COAHG = -5395.99 + \underset{(27.89)}{0.837}\ COAPL + \underset{(4.16)}{82.04}\ COYHG$$

$R^2 = 0.990$ RMSE = 766.58 CV = 1.19 Estimation period = 1965-1981

3. Corn yield per harvested acre, enters the model in the fourth quarter

$$COYHG = 210.78 - \underset{(1.81)}{0.000507}\ COAPL + \underset{(3.22)}{3.00}\ JP - \underset{(3.79)}{1.54}\ JT + \underset{(5.57)}{2.47}\ COTA - \underset{(3.09)}{10.44}\ D70 - \underset{(2.47)}{8.45}\ D74$$

$R^2 = 0.966$ RMSE = 2.77 CV = 3.16 Estimation period = 1965-1981

4. Corn production, enters the model in the fourth quarter

$$COSPR = COYHG \cdot COAHG/1000$$

$R^2 = 0.987$ RMSE = 143.17 CV = 2.52 Estimation period = 1965-1981

Corn sector, quarterly equations

5. Corn beginning stocks

$$COCIT = COCOT_{t-1}$$

6. Corn total supply

$$COSST = COSPR + COCIT + COSMT$$

7. Corn adjusted feed use, even quarters

$$COUFEADJ = -56.58 + \underset{(18.93)}{0.923}\ COUFEADJ_{t-4} - \underset{(4.61)}{188.30}\ COPFM - \underset{(1.88)}{0.666}\ SMPDM_{t-1} + \underset{(3.98)}{2.86}\ PR7LV_{t-2} + \underset{(3.02)}{0.0421}\ CAOF$$

$R^2 = 0.939$ RMSE = 81.87 CV = 8.11 Estimation period = 1973:3-1981

8. Corn feed use, uneven quarters

$$COUFE = COUFEADJ\ [D1 + D2(2/3) + D3(4/3) + D4]$$

9. Corn per capita food and industrial use, even quarters

$$COUFDPCA = 0.232 - \underset{(1.11)}{3.30}\ COPFM/CPI + \underset{(1.24)}{1.97}\ WHPFM/CPI - \underset{(3.75)}{0.0415}\ D2 + \underset{(16.99)}{0.0251}\ COTA + \underset{(3.31)}{0.00415}\ COTA \cdot D3$$
$$+ \underset{(5.04)}{0.169}\ D8003 + \underset{(7.49)}{0.257}\ D8103F03$$

$R^2 = 0.946$ RMSE = 0.029 CV = 5.70 Estimation period = 1971-1981

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Corn sector, quarterly equations—continued

10. Corn food and industrial use, uneven quarters

$$COUFD = POP \cdot COUFDPCA \cdot [D1 + D2(2/3) + D3(4/3) + D4]$$

11. Corn per capita alcoholic beverage use

$$COUALCPC = 0.0521 + \underset{(1.44)}{0.00711}\ Y/CPI + \underset{(2.84)}{0.00690}\ D1 - \underset{(5.05)}{0.0122}\ D2 + \underset{(15.26)}{0.0370}\ D3 - \underset{(2.40)}{0.000413}\ TQ$$

$R^2 = 0.923$ RMSE = 0.0057 CV = 6.89 Estimation period = 1971-1981

12. Corn alcoholic beverage use

$$COUALC = COUALCPC \cdot POP$$

13. Corn seed use, estimated annually by crop year; distributed over the corresponding calendar year quarters: 0 in the fourth quarter, 20 percent in the first and third quarters, 60 percent in the second quarter

$$COUSE = -6.16 + \underset{(5.07)}{0.000242}\ COAPL_{L+1} + \underset{(1.83)}{110.14}\ COPFM \cdot D1/PPFZ2 + \underset{(3.87)}{0.290}\ COTA$$

$R^2 = 0.973$ RMSE = 0.61 CV = 3.69
Annual estimation period = 1964-1980
Derived quarterly estimation period = 1964:4-1981:3

14. Corn total utilization

$$COUUT = COUFE + COUFD + COUALC + COUSE + COUXT$$

15. Corn ending privately held free stocks

$$COCCTP = COSST - COUUT - COCCTC - CONEN - COFOR - COFOREX$$

16. Corn total ending stocks

$$COCOT = COCCTP + COCCTC + CONEN + COFOR + COFOREX$$

17. Corn price

$$COPFM = -0.187 + \underset{(12.72)}{0.757}\ COPFM_{t-1} - \underset{(4.29)}{0.000265}\ COSST + \underset{(4.46)}{0.00132}\ COUUT\ [D1 + D2(3/2) + D3(3/4) + D4]$$

$$- \underset{(2.37)}{0.00353}\ (COAPL/1000) \cdot (D2 + D3) - \underset{(2.76)}{0.144}\ JP + \underset{(3.20)}{0.00992}\ JT$$

$R^2 = 0.905$ RMSE = 0.21 CV = 9.42 Estimation period = 1971-1981

Wheat sector, annual equations

1. Wheat acres planted, enters the model in the fourth quarter, but is solved for in the model in the third quarter

$$WHAPL = 48958.02 + \underset{(3.43)}{15819.61}\ WHPHR - \underset{(1.52)}{11073.21}\ COPHR$$

$R^2 = 0.881$ RMSE = 4293.89 CV = 6.52 Estimation period = 1965-1981

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Wheat sector, annual equations—continued

2. Wheat acres harvested for grain, enters the model in the third quarter

$$WHAHG = -\ 1727.73 + \underset{(28.53)}{0.916}\ WHAPL$$

$R^2 = 0.982$ RMSE = 1493.21 CV = 2.55 Estimation period = 1965-1981

3. Wheat yield per harvested acre, enters the model in the third quarter

$$WHYHG = 35.48 - \underset{(4.99)}{0.000163}\ WHAPL + \underset{(10.03)}{0.755}\ WHTA + \underset{(2.81)}{2.68}\ D71 - \underset{(3.71)}{3.37}\ D74 - \underset{(3.15)}{3.11}\ D78$$

$R^2 = 0.934$ RMSE = 0.87 CV = 2.85 Estimation period = 1965-1981

4. Wheat production, enters the model in the third quarter

$$WHSPR = WHYHG \cdot WHAHG/1000$$

$R^2 = 0.985$ RMSE = 97.92 CV = 6.15 Estimation period = 1965-1981

Wheat sector, quarterly equations

5. Wheat beginning stocks

$$WHCIT = WHCOT_{t-1}$$

6. Wheat total supply

$$WHSST = WHSPR + WHCIT + WHSMT$$

7. Wheat feed use

$$WHUFE = -\ 108.39 + \underset{(4.31)}{39.26}\ D1 - \underset{(0.72)}{6.52}\ D2 - \underset{(2.44)}{436.49}\ D3 + (D1 + D2 + D4) \cdot (\underset{(2.08)}{0.0184}\ STHFFQ - \underset{(1.84)}{13.46}\ WHPFM + \underset{(1.19)}{15.32}\ COPFM)$$

$$+ D3 \cdot (\underset{(2.75)}{0.0338}\ CAOF + \underset{(2.39)}{0.000398}\ TUQ - \underset{(5.54)}{235.60}\ WHPFM + \underset{(4.04)}{274.72}\ COPFM + \underset{(3.64)}{0.826}\ SMPDM - \underset{(7.12)}{207.19}\ D7603)$$

$R^2 = 0.910$ RMSE = 19.88 CV = 62.81 Estimation period = 1971-1981

8. Wheat per capita food use

$$WHUFDPC = 0.637 - \underset{(1.03)}{1.08}\ WHPFM/CPI + \underset{(1.20)}{2.37}\ BAPFM/CPI - \underset{(4.38)}{0.0316}\ D1 - \underset{(36.82)}{0.268}\ D2 + \underset{(25.65)}{0.185}\ D3 + \underset{(3.73)}{0.000563}\ TQ$$

$R^2 = 0.987$ RMSE = 0.020 CV = 3.04 Estimation period = 1967-1981

9. Wheat food use

$$WHUFD = WHUFDPC \cdot POP$$

10. Wheat seed use, estimated using second, third, and fourth quarters only; first quarter set exogenously in simulations; summary statistics for estimated equation reported without first quarter observations

$$WHUSE = -\ 1.04 + \underset{(7.85)}{0.000424}\ WHAPL_{L+1} + \underset{(1.62)}{0.244}\ WHTA - \underset{(8.44)}{7.57}\ D2 - \underset{(1.11)}{0.993}\ D3$$

$R^2 = 0.904$ RMSE = 2.44 CV = 9.01 Estimation period = 1967:2-1981:4

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Wheat sector, quarterly equations—continued

11. Wheat total utilization

$$WHUUT = WHUFE + WHUFD + WHUSE + WHUXT$$

12. Wheat ending privately held free stocks

$$WHCCTP = WHSST - WHUUT - WHCCTC - WHNEN - WHFOR$$

13. Wheat total ending stocks

$$WHCOT = WHCCTP + WHCCTC + WHNEN + WHFOR$$

14. Wheat price

$$WHPFM = 0.229 + \underset{(13.50)}{0.822}\ WHPFM_{t-1} - \underset{(3.30)}{0.000552}\ WHSST + \underset{(3.71)}{0.00356}\ WHUUT\ [D1 + D2(3/2) + D3(3/4) + D4]$$

$$- \underset{(2.25)}{0.00563}\ (WHAPL/1000) \cdot D1 - \underset{(3.41)}{0.0106}\ (WHAPL/1000) \cdot D2$$

$R^2 = 0.881$ RMSE = 0.38 CV = 12.40 Estimation period = 1971-1981

Soybean sector, annual equations

1. Soybean acres planted, enters the model in the second quarter

$$SBAPL = 28876.16 + \underset{(1.31)}{126714.0}\ SBPFM \cdot D1/PPFZ2 - \underset{(1.05)}{1927.11}\ COPHR + \underset{(8.27)}{2381.42}\ (SBTA+1)$$

$R^2 = 0.932$ RMSE = 3389.36 CV = 6.56 Estimation period = 1965-1981

2. Soybean acres harvested, enters the model in the fourth quarter

$$SBAHB = -1710.14 + \underset{(2.13)}{77.96}\ SBYHB + \underset{(135.18)}{0.971}\ SBAPL$$

$R^2 = 0.9996$ RMSE = 246.67 CV = 0.49 Estimation period = 1965-1981

3. Soybean yield per harvested acre, enters the model in the fourth quarter

$$SBYHB = 25.00 - \underset{(0.33)}{0.0000388}\ SBAPL + \underset{(1.26)}{0.327}\ SBTA - \underset{(1.86)}{3.03}\ D74 + \underset{(1.59)}{2.81}\ D79 + \underset{(1.24)}{0.454}\ JP$$

$R^2 = 0.754$ RMSE = 1.37 CV = 5.01 Estimation period = 1965-1981

4. Soybean production, enters the model in the fourth quarter

$$SBSPR = SBAHB \cdot SBYHB/1000$$

$R^2 = 0.975$ RMSE = 63.47 CV = 4.52 Estimation period = 1965-1981

Soybean sector, quarterly equations

5. Soybean beginning stocks, uneven quarters

$$SBCIT = SBCOT_{t-1}$$

6. Soybean total supply, uneven quarters

$$SBSST = SBCIT + SBSPR$$

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Soybean sector, quarterly equations—continued

7. Soybean crush (demand for soybean crushings derived from the meal product market), even quarters

$$SBUCR = SMSPR/SMYCR$$

8. Soybean crush, uneven quarters

$$SBUCRUN = SBUCR - (D2 + D3) \cdot SBUCR/3 + (D3 + D4) \cdot (SBUCR_{t-1} - SBUCRUN_{t-1}) + D4 \cdot (SBUCR_{t-2} - SBUCRUN_{t-2})$$

9. Soybean total use, uneven quarters

$$SBUUTUN = SBUCRUN + SBUXTUN + SBUSFRUN$$

10. Soybean ending stocks, uneven quarters

$$SBCOT = SBSST - SBUUTUN$$

11. Soybean price

$$SBPFM = -0.941 + \underset{(7.67)}{0.080}\ SOPDM + \underset{(7.93)}{0.0142}\ SMPDM + (\underset{(3.76)}{0.274}\ D1 + \underset{(3.19)}{0.246}\ D2 + \underset{(3.34)}{0.249}\ D3 + \underset{(2.28)}{0.171}\ D4)\ SBPFM_{t-1}$$

$$+ (\underset{(0.13)}{0.128}\ D1 + \underset{(0.65)}{0.426}\ D2 + \underset{(0.86)}{0.139}\ D3 + \underset{(0.93)}{1.46}\ D4)\ [SBCOT/(SBUCR + SBUXT)]^{-1} + \underset{(2.16)}{0.00702}\ PCED + \underset{(1.60)}{0.737}\ D7303$$

$R^2 = 0.963$ RMSE = 0.36 CV = 6.23 Estimation period = 1971-1981

Soybean meal sector, quarterly equations

1. Soybean meal yield

$$SMYCR = 23.80 - \underset{(1.15)}{0.00105}\ SBUCR + \underset{(2.35)}{0.0215}\ SBTA$$

$R^2 = 0.126$ RMSE = 0.17 CV = 0.70 Estimation period = 1966-1981

2. Soybean meal production

$$SMSPR = 31.30 + \underset{(51.82)}{0.989}\ SMUDT + \underset{(30.25)}{1.03}\ SMUXT - \underset{(1.10)}{32.42}\ D1 - \underset{(1.30)}{33.63}\ D2 - \underset{(2.46)}{61.28}\ D3$$

$R^2 = 0.998$ RMSE = 54.26 CV = 1.05 Estimation period = 1971-1981

3. Soybean meal beginning stocks

$$SMCIT = SMCOT_{t-1}$$

4. Soybean meal supply, total

$$SMSST = SMCIT + SMSPR$$

5. Soybean meal domestic use

$$SMUDT = 124.64 - \underset{(6.05)}{7.45}\ SMPDM_{t-1} - \underset{(2.08)}{286.73}\ COPFM_{t-1} + \underset{(5.78)}{19.35}\ PR7LV_{t-1}$$

$$+ \underset{(2.71)}{21.09}\ HAPFC + \underset{(4.16)}{0.216}\ CANPL + \underset{(0.70)}{0.120}\ HOSWF_{t-1} + \underset{(2.38)}{0.421}\ HOSWF_{t-2}$$

$R^2 = 0.886$ RMSE = 266.81 CV = 6.74 Estimation period = 1973:3-1981

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Soybean meal sector, quarterly equations—continued

6. Soybean meal use, total

$$SMUUT = SMUDT + SMUXT$$

7. Soybean meal ending stocks

$$SMCOT = SMSST - SMUUT$$

8. Soybean meal price, 44-percent protein, Decatur[2]

$$SMPDM = 0.0611 + \underset{(0.22)}{0.000509}\ SMUUT - \underset{(0.50)}{0.00124}\ SMSST + \underset{(6.36)}{0.453}\ SMPDM_{t-1}$$

$$- \underset{(2.97)}{1.31}\ SOPDM_{t-1} + \underset{(3.01)}{0.793}\ PR7LV + \underset{(5.96)}{133.47}\ D7302 + \underset{(5.44)}{5.59}\ SBPFM_{t-1}$$

$R^2 = 0.881$ RMSE = 21.34 CV = 16.02 Estimation period = 1965-1981

Soybean oil sector, quarterly equations

1. Soybean oil yield

$$SOYCR = 10.52 - \underset{(0.23)}{0.000281}\ SBUCR + \underset{(2.43)}{0.0281}\ SBTA + \underset{(0.78)}{0.0523}\ D1 + \underset{(2.67)}{0.184}\ D2 + \underset{(3.16)}{0.242}\ D3$$

$R^2 = 0.416$ RMSE = 0.19 CV = 1.74 Estimation period = 1966-1981

2. Soybean oil production

$$SOSPR = SBUCR \cdot SOYCR$$

3. Soybean oil beginning stocks

$$SOCIT = SOCOT_{t-1}$$

4. Soybean oil supply, total

$$SOSST = SOCIT + SOSPR$$

5. Soybean oil domestic use, per capita

$$SOUDTPC = -3.80 - \underset{(4.62)}{4.57}\ SOPDM/PCED + \underset{(28.27)}{324.45}\ Y/POP/PCED + \underset{(4.36)}{1.89}\ D7401 - \underset{(1.48)}{0.207}\ D1 - \underset{(3.30)}{0.451}\ D2 - \underset{(3.19)}{0.437}\ D3$$

$R^2 = 0.933$ RMSE = 0.40 CV = 4.98 Estimation period = 1965-1981

6. Soybean oil domestic use, total

$$SOUDT = SOUDTPC \cdot POP$$

7. Soybean oil use, total

$$SOUUT = SOUDT + SOUXT$$

8. Soybean oil ending stocks

$$SOCOT = SOSST - SOUUT$$

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Soybean oil sector, quarterly equations—continued

9. Soybean oil price

$$SOPDM = -0.450 - \underset{(0.33)}{0.000563}\ SOSST + \underset{(0.93)}{0.00294}\ SOUUT + \underset{(8.96)}{0.742}\ SOPDM_{t-1} + \underset{(2.76)}{5.751}\ D73MY + \underset{(2.34)}{0.0408}\ JT$$

$R^2 = 0.777$ RMSE = 3.73 CV = 16.72 Estimation period = 1971-1981

Cattle sector, annual equations

1. Cow inventory, January 1

$$CWK = 0.980\ CWK_{L-1} - CWQA_{L-1} + HFN_{L-1}$$

2. Steers over 500 pounds on farms, January 1

$$STG5K = 2369.22 + \underset{(1.36)}{3615.30}\ (STEPA/GNPDA)_{L-1} + \underset{(3.62)}{0.268}\ CVQ_{L-1}$$

$R^2 = 0.526$ RMSE = 670.96 CV = 4.18 Estimation period = 1967-1981

3. Heifers over 500 pounds on farms, January 1

$$HFG5K = -1792.35 + \underset{(1.70)}{3742.83}\ (STEPA/GNPDA)_{L-1} + \underset{(6.32)}{0.387}\ CVQ_{L-1}$$

$R^2 = 0.769$ RMSE = 555.25 CV = 3.18 Estimation period = 1967-1981

4. Heifers kept for cow replacement

$$HFR = -1569.58 + \underset{(13.06)}{0.280}\ CWK - \underset{(5.63)}{13029.59}\ (CWQA/CWK)_{L-1}$$

$R^2 = 0.941$ RMSE = 240.92 CV = 2.26 Estimation period = 1967-1981

5. Proportion of heifers kept for replacement that actually enter the cow herd

$$HFNP = 0.0289 + \underset{(1.06)}{1.95}\ (STEPA/GNPDA) - \underset{(1.17)}{2.60}\ (STEPA/GNPDA)^2 - \underset{(1.10)}{0.272}\ (HAPFMSA/GNPDA) + \underset{(2.50)}{0.010}\ (CWK/1000)$$

$$+ \underset{(2.32)}{0.074}\ D74 + \underset{(3.54)}{0.1137}\ D80$$

$R^2 = 0.815$ RMSE = 0.026 CV = 3.25 Estimation period = 1967-1981

6. Heifers actually entering the cow herd

$$HFN = HFR \bullet HFNP$$

7. Calving rate

$$CVQP = 0.760 + \underset{(5.42)}{1.30}\ (HFR/CWK) + \underset{(5.77)}{0.165}\ [(STEPA/GNPDA)_{L-1} - (STEPA/GNPDA)_{L-2}] - \underset{(9.26)}{0.357}\ (HAPFMSA/GNPDA) - \underset{(4.34)}{0.0351}\ D79$$

$R^2 = 0.960$ RMSE = 0.0068 CV = 0.75 Estimation period = 1967-1981

8. Calf crop

$$CVQ = CWK \bullet CVQP$$

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Cattle sector, quarterly equations

9. Cow slaughter[3]

$$CWQ = -\underset{(3.60)}{12.10}\ STEPWA3 + \underset{(13.48)}{0.0554}\ CWK - \underset{(2.15)}{0.00740}\ CWK \cdot D1 - \underset{(2.87)}{0.00987}\ CWK \cdot D2 - \underset{(1.68)}{0.00576}\ CWK \cdot D3$$

$R^2 = 0.499$ RMSE = 416.32 CV = 21.41 Estimation period = 1971-1981

10. Bull slaughter

$$CBQ = 50.18 + \underset{(15.01)}{0.0614}\ CWQ + \underset{(2.77)}{0.0304}\ CWQ \cdot D2 + \underset{(7.12)}{0.0175}\ CWQ \cdot D3 + \underset{(1.75)}{1.13}\ TA - \underset{(1.29)}{25.97}\ D2$$

$R^2 = 0.909$ RMSE = 13.56 CV = 6.88 Estimation period = 1971-1981

11. Net cattle placements on feed, 13 States[3]

$$CANPL = \underset{(7.31)}{118.97}\ (STFPWA3/COPFM_{t-1}) - \underset{(4.50)}{41.52}\ STEPWA3 + \underset{(0.28)}{0.00465}\ CVQ_{L-1} \cdot D1 + \underset{(0.64)}{0.0105}\ CVQ_{L-1} \cdot D2 + \underset{(1.04)}{0.0168}\ CVQ_{L-1} \cdot D3$$

$$+ \underset{(3.22)}{0.0518}\ CVQ \cdot D4 + \underset{(4.20)}{1659.53}\ LOG(TA)$$

$R^2 = 0.787$ RMSE = 509.95 CV = 9.33 Estimation period = 1971-1981

12. Cattle on feed, 13 States

$$CAOF = CAOF_{t-1} + CANPL_{t-1} - CAFQ_{t-1}$$

13. Fed cattle marketed, 13 States

$$CAFQ = 1763.76 + \underset{(7.73)}{0.231}\ (CAOF + CANPL) + \underset{(3.09)}{0.0239}\ (CAOF + CANPL) \cdot D1 + \underset{(2.23)}{0.0184}\ (CAOF + CANPL) \cdot D2$$

$$+ \underset{(2.54)}{0.0214}\ (CAOF + CANPL) \cdot D3$$

$R^2 = 0.643$ RMSE = 282.58 CV = 5.14 Estimation period = 1971-1981

14. Fed steer and heifer slaughter

$$STHFFQ = 43.06 + \underset{(36.61)}{1.13}\ CAFQ + \underset{(3.33)}{0.0206}\ CAFQ \cdot D2 + \underset{(2.99)}{0.0184}\ CAFQ \cdot D3$$

$R^2 = 0.971$ RMSE = 90.80 CV = 1.44 Estimation period = 1971-1981

15. Nonfed steer and heifer slaughter[3]

$$STHFNFQ = -\underset{(7.05)}{38.97}\ STFPWA3 + \underset{(2.77)}{331.97}\ COPFM_{t-1} - \underset{(4.52)}{0.403}\ STHFFQ + \underset{(3.16)}{0.0354}\ CVQ_{L-1} \cdot D1 + \underset{(3.32)}{0.0364}\ CVQ_{L-1} \cdot D2$$

$$+ \underset{(3.77)}{0.0410}\ CVQ_{L-1} \cdot D3 + \underset{(3.78)}{0.0411}\ CVQ \cdot D4 + \underset{(4.57)}{1141.66}\ LOG(TA)$$

$R^2 = 0.859$ RMSE = 217.67 CV = 25.54 Estimation period = 1971-1981

16. Total steer and heifer slaughter

$$STHFTQ = STHFFQ + STHFNFQ$$

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Cattle sector, quarterly equations—continued

17. Commercial cattle slaughter

$$CATQ = STHFTQ + CWQ + CBQ$$

18. Cattle, average dressed weight, commercial production

$$CAADW = 516.02 + \underset{(6.01)}{0.685}\ STFPWA3 + \underset{(9.94)}{17.216}\ (STHFTQ/CWQ)$$

$R^2 = 0.791$ RMSE = 9.19 CV = 1.49 Estimation period = 1971-1981

19. Beef production, commercial

$$BEQC = CATQ \cdot CAADW/1000$$

20. Beef production, total

$$BEQT = BEQC + BEQF$$

21. Beginning beef stocks, cold storage

$$BECIT = BECOT_{t-1}$$

22. Total beef supply

$$BESST = BECIT + BEQT + BESMT$$

23. Ending beef stocks, cold storage

$$BECOT = -60.32 + BECIT\ (\underset{(4.53)}{0.893}\ D1 + \underset{(5.12)}{0.835}\ D2 + \underset{(4.17)}{0.631}\ D3 + \underset{(4.61)}{0.783}\ D4)$$

$$+ BESMT\ (\underset{(1.55)}{0.214}\ D1 + \underset{(1.58)}{0.180}\ D2 + \underset{(2.37)}{0.282}\ D3 + \underset{(3.67)}{0.398}\ D4)$$

$R^2 = 0.710$ RMSE = 39.66 CV = 11.44 Estimation period = 1971-1981

24. Civilian beef consumption, carcass weight

$$BEUCCC = BESST - BECOT - BEUXT - BEUSH - BEUML$$

25. Civilian per capita beef consumption, carcass weight

$$BEUCCCPC = BEUCCC/POPCIV$$

26. Civilian per capita beef consumption, retail weight

$$BEUCCRPC = 0.740\ BEUCCCPC$$

27. Fed steer price

$$STEP = -100.72 - \underset{(7.55)}{0.00959}\ STHFFQ - \underset{(9.81)}{0.0128}\ STHFNFQ + \underset{(13.96)}{29.34}\ LOG(YMA8) + \underset{(2.42)}{537.04}\ YMA8LC + \underset{(2.25)}{2.60}\ D2 + \underset{(2.96)}{3.40}\ D3$$

$R^2 = 0.950$ RMSE = 2.95 CV = 5.93 Estimation period = 1972-1981

28. Cattle price, farm

$$CAPFM = -123.66 - \underset{(5.80)}{0.00709}\ STHFFQ - \underset{(13.10)}{0.0164}\ STHFNFQ + \underset{(14.79)}{29.88}\ LOG(YMA8) + \underset{(2.86)}{608.30}\ YMA8LC + \underset{(2.12)}{2.35}\ D2 + \underset{(2.88)}{3.19}\ D3$$

$R^2 = 0.960$ RMSE = 2.84 CV = 6.33 Estimation period = 1972-1981

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Cattle sector, quarterly equations—continued

29. Calf price, farm

$$CVPFM = 93.18 - \underset{(2.33)}{0.00180\ CVQ_{L-1}} + \underset{(7.99)}{1.50\ STFP} - \underset{(2.40)}{7.29\ COPFM_{t-1}} + \underset{(1.05)}{2.48\ D1} - \underset{(1.07)}{0.215\ TQ}$$

$R^2 = 0.898$ RMSE = 6.75 CV = 13.16 Estimation period = 1971-1981

30. Feeder steer price

$$STEP = 54.72 - \underset{(2.19)}{0.00109\ CVQ_{L-1}} + \underset{(11.33)}{1.24\ STFP} - \underset{(1.62)}{5.54\ COPFM_{t-1}}$$

$R^2 = 0.931$ RMSE = 4.65 CV = 9.06 Estimation period = 1971-1981

Hog sector, quarterly equations

1. Sows farrowing, 10 States

$$HOSWF = -788.76 + \underset{(4.42)}{23.53\ HOP7MWA3} - \underset{(1.68)}{109.17\ COPFM_{t-1}} + \underset{(6.78)}{0.660\ HOSWF_{t-1}} + \underset{(11.83)}{0.892\ HOSWF_{t-4}} - \underset{(5.10)}{0.533\ HOSWF_{t-5}}$$

$R^2 = 0.901$ RMSE = 122.00 CV = 5.17 Estimation period = 1975-1981

2. Pig crop, 10 States

$$HOPGQ = HOSWF \cdot HOPGQRAT$$

3. Barrow and gilt slaughter

$$HOBGQ = -658.92 + \underset{(7.60)}{0.439\ HOPGQ_{t-1}} + \underset{(14.58)}{0.694\ HOPGQ_{t-2}} + \underset{(4.07)}{1268.64\ D1} + \underset{(5.59)}{2028.89\ D2}$$

$R^2 = 0.929$ RMSE = 685.07 CV = 3.58 Estimation period = 1974-1981

4. Sow slaughter

$$HOSWQ = 705.61 + \underset{(6.50)}{0.458\ HOSWF_{t-1}} - \underset{(5.03)}{18.75\ HOP7MWA3} + \underset{(2.69)}{133.90\ COPFM} - \underset{(5.50)}{286.17\ D1} - \underset{(2.75)}{152.38\ D2} - \underset{(4.02)}{232.25\ D3}$$

$R^2 = 0.861$ RMSE = 103.87 CV = 9.11 Estimation period = 1974-1981

5. Boar slaughter

$$HOBRQ = 71.21 + \underset{(4.56)}{0.0614\ HOSWQ} + \underset{(2.63)}{0.0147\ HOSWQ \cdot D2} - \underset{(5.69)}{2.50\ HOP7MWA3} + \underset{(11.79)}{13.92\ TA}$$

$R^2 = 0.855$ RMSE = 16.89 CV = 8.24 Estimation period = 1971-1981

6. Hog slaughter

$$HOQ = HOBGQ + HOSWQ + HOBRQ$$

7. Pork production, commercial

$$POQC = HOQ \cdot HOADW/1000$$

8. Pork production, total

$$POQT = POQC + POQF$$

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Hog sector, quarterly equations—continued

9. Beginning pork stocks, cold storage

$$POCIT = POCOT_{t-1}$$

10. Total pork supply

$$POSST = POCIT + POQT + POSMT$$

11. Ending pork stocks, cold storage

$$POCOT = -25.46 + POCIT\ (\underset{(4.25)}{0.874}\ D1 + \underset{(5.35)}{0.940}\ D2 + \underset{(3.81)}{0.550}\ D3 + \underset{(3.55)}{0.783}\ D4)$$

$$+ POQT\ (\underset{(1.11)}{0.0215}\ D1 + \underset{(0.93)}{0.0163}\ D2 + \underset{(1.08)}{0.0191}\ D3 + \underset{(2.31)}{0.0339}\ D4)$$

$R^2 = 0.860$ RMSE = 27.68 CV = 10.39 Estimation period = 1971-1981

12. Civilian pork consumption, carcass weight

$$POUCCC = POSST - POCOT - POUXT - POUSH - POUML$$

13. Civilian per capita pork consumption, carcass weight

$$POUCCCPC = POUCCC/POPCIV$$

14. Civilian per capita pork consumption, retail weight

$$POUCCRPC = POUCCCPC \cdot POCRWGT$$

15. Barrow and gilt price, 7 markets

$$HOP7M = -27.34 - \underset{(15.35)}{0.0238}\ POQT - \underset{(4.39)}{0.00599}\ BEQT + \underset{(12.45)}{26.11}\ LOG(YMA8) + \underset{(2.07)}{362.89}\ YMA8LC - \underset{(4.51)}{5.13}\ D1 - \underset{(6.97)}{9.48}\ D2 - \underset{(6.70)}{9.94}\ D3$$

$R^2 = 0.929$ RMSE = 2.33 CV = 5.64 Estimation period = 1972-1981

16. Hog price, farm

$$HOPFM = -0.0213 + \underset{(189.94)}{0.976}\ HOP7M - \underset{(1.12)}{0.148}\ D2 - \underset{(2.95)}{0.391}\ D3$$

$R^2 = 0.999$ RMSE = 0.37 CV = 1.01 Estimation period = 1970-1981

Poultry sector, quarterly equations

1. Broiler pullets placed in hatchery supply flocks

$$BRPL = 904.09 + \underset{(3.96)}{0.413}\ BRPL_{t-4} - \underset{(3.69)}{504.05}\ FGPFM_{t-2} + \underset{(2.04)}{58.56}\ BRP9C_{t-2} + \underset{(2.37)}{555.35}\ D2 + \underset{(4.35)}{65.05}\ TQ$$

$R^2 = 0.791$ RMSE = 605.17 CV = 6.97 Estimation period = 1971-1981

2. Broiler hatch

$$BRH = -33916.46 + \underset{(8.48)}{19.28}\ BRPLWS3_{t-2} + \underset{(3.34)}{4373.39}\ BRP9C_{t-1} - \underset{(3.80)}{23177.01}\ FGPFM_{t-1} + \underset{(6.45)}{80192.47}\ D1 + \underset{(12.32)}{144647.0}\ D2$$

$$+ \underset{(4.72)}{56542.23}\ D3 + \underset{(8.53)}{6185.78}\ TQ$$

$R^2 = 0.964$ RMSE = 26703.49 CV = 2.95 Estimation period = 1971-1981

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Poultry sector, quarterly equations—continued

3. Broiler production

$$BRQ = -391468.0 + \underset{(15.79)}{2.37}\ BRH_{t-1} + \underset{(2.33)}{4351.13}\ BRP9C_{t-1} - \underset{(1.38)}{13414.07}\ FGPFM_{t-1}$$

$$+ \underset{(5.03)}{101577.0}\ D1 + \underset{(6.99)}{129912.0}\ D2 - \underset{(2.48)}{57060.73}\ D3 + \underset{(3.85)}{7006.39}\ TQ$$

$R^2 = 0.990$ RMSE = 41645.09 CV = 1.77 Estimation period = 1971-1981

4. Beginning stocks, young chickens

$$BRCIT = BRCOT_{t-1}$$

5. Total chicken supply

$$BRSST = BRCIT + BRQ$$

6. Ending stocks, young chickens

$$BRCOT = -1085.26 + BRCIT\ (\underset{(7.99)}{0.771}\ D1 + \underset{(8.10)}{0.875}\ D2 + \underset{(3.35)}{0.543}\ D3 + \underset{(8.68)}{0.963}\ D4) + \underset{(1.07)}{0.00175}\ BRQ + \underset{(1.91)}{10219.19}\ D3$$

$R^2 = 0.717$ RMSE = 3736.52 CV = 13.28 Estimation period = 1971-1981

7. Civilian consumption, young chickens

$$BRUCC = BRSST - BRCOT - BRUXT - BRUSH - BRUML$$

8. Civilian per capita consumption, young chickens

$$BRUCCPC = BRUCC/POPCIV/1000$$

9. Broiler price, 9-city

$$BRP9C = -165.03 - \underset{(4.48)}{0.0233}\ (BRQ/1000) - \underset{(4.83)}{0.00751}\ BEQT - \underset{(4.20)}{0.00857}\ POQT$$

$$+ \underset{(7.83)}{46.57}\ LOG(YMA4) + \underset{(1.17)}{143.56}\ YMA4LC + \underset{(1.43)}{2.42}\ D2 + \underset{(1.29)}{2.35}\ D3$$

$R^2 = 0.855$ RMSE = 2.66 CV = 6.37 Estimation period = 1972-1981

10. Broiler price, farm

$$BRPFM = -6.03 + \underset{(86.68)}{0.684}\ BRP9C - \underset{(1.52)}{0.139}\ D3 + \underset{(5.56)}{0.0247}\ TQ$$

$R^2 = 0.998$ RMSE = 0.25 CV = 1.09 Estimation period = 1971-1981

11. Turkey production

$$TUQ = 429556.0 + \underset{(2.65)}{4503.30}\ TUPFM_{t-2} - \underset{(2.21)}{31789.13}\ COPFM_{t-2} - \underset{(28.04)}{475734.0}\ D1 - \underset{(18.89)}{338739.0}\ D2 + \underset{(2.92)}{3218.47}\ TQ$$

$R^2 = 0.964$ RMSE = 45409.95 CV = 8.74 Estimation period = 1971-1981

12. Beginning stocks, turkeys

$$TUCIT = TUCOT_{t-1}$$

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model equations[1]—Continued

Poultry sector, quarterly equations—continued

13. Total turkey supply

$$TUSST = TUCIT + TUQ$$

14. Ending stocks, turkeys

$$TUCOT = -\,83389.40 + TUCIT\ (\underset{(5.14)}{0.857\ D1} + \underset{(4.26)}{0.921\ D2} + \underset{(2.97)}{0.490\ D3} + \underset{(2.00)}{0.277\ D4})$$

$$+\ TUQ\ (\underset{(2.74)}{0.263\ D1} + \underset{(3.77)}{0.340\ D2} + \underset{(7.91)}{0.567\ D3} + \underset{(2.85)}{0.255\ D4})$$

$R^2 = 0.943$ RMSE = 30457.75 CV = 12.04 Estimation period = 1971-1981

15. Civilian consumption, turkeys

$$TUUCC = TUSST - TUCOT - TUUXT - TUUSH - TUUML$$

16. Civilian per capita consumption, turkeys

$$TUUCCPC = TUUCC/POPCIV/1000$$

17. Turkey price, farm

$$TUPFM = -\,84.40 - \underset{(2.78)}{0.00594\ OTHERTUQT} + \underset{(5.27)}{25.84\ LOG(YMA4)} + \underset{(2.09)}{357.85\ YMA4LC} - \underset{(2.35)}{4.23\ D1} - \underset{(3.17)}{6.04\ D2} - \underset{(2.63)}{5.47\ D3}$$

$R^2 = 0.757$ RMSE = 3.73 CV = 10.72 Estimation period = 1972-1981

Aggregate livestock sector variable, quarterly equation

1. Prices received by farmers for livestock

$$PR7LV = [0.666((480\ CAPFM + 37\ CVPFM + 212\ HOPFM)/24442.1)$$

$$+\ 0.135((56.69\ EGPFM + 23.83\ TUPFM + 111.11\ BRPFM)/4768.3)$$

$$+\ 0.199((1120\ MIPFM)/7156.8)]\ (399.16)(0.20772)$$

[1]"L" subscripts on variables denote annual lags, "t" subscripts denote quarterly lags. No subscript on variables denotes current period observations (year or quarter, as appropriate).

[2]Estimates of the soybean meal price equation result from a principal components regression undertaken to address extreme collinearity in the regressors. R^2 is derived using (SST − SSE)/SST, where SST is the mean corrected total sum of squares of meal prices and SSE is the sum of squared errors.

[3]Cattle sector equations 9, 11, and 15 were estimated with intercepts constrained to equal zero. The resulting bias and systematic errors were not statistically significant.

Appendix B—Variable Definitions

Quarterly agriculture forecasting model variable definitions

Variables	Definition	Units
Endogenous		
BECIT	Beginning beef stocks, cold storage	Mil. lbs.
BECOT	Ending beef stocks, cold storage	Mil. lbs.
BEQC	Beef production, commercial	Mil. lbs.
BEQT	Beef production, total	Mil. lbs.
BESST	Total beef supply	Mil. lbs.
BEUCCC	Civilian beef consumption, carcass weight	Mil. lbs.
BEUCCCPC	Civilian per capita beef consumption, carcass weight	Pounds/person
BEUCCRPC	Civilian per capita beef consumption, retail weight	Pounds/person
BRCIT	Beginning stocks, young chickens	1,000 lbs.
BRCOT	Ending stocks, young chickens	1,000 lbs.
BRH	Broiler hatch	1,000 chicks
BRPFM	Broiler price, farm	$/cwt
BRPL	Broiler pullets placed in hatchery supply flocks	1,000 pullets
BRPLWS3	Moving weighted sum of BRPL*	1,000 pullets
BRP9C	Broiler price, nine-city	$/cwt
BRQ	Broiler production	1,000 lbs.
BRSST	Total chicken supply	1,000 lbs.
BRUCC	Civilian consumption, young chickens	1,000 lbs.
BRUCCPC	Civilian per capita consumption, young chickens	Pounds/person
CAADW	Cattle, average dressed weight, commercial production	Pounds
CAFQ	Fed cattle marketed, 13 States	1,000 head
CANPL	Net cattle placements on feed, 13 States	1,000 head
CAOF	Cattle on feed, 13 States	1,000 head
CAPFM	Cattle price, farm	$/cwt
CATQ	Commercial cattle slaughter	1,000 head
CBQ	Bull slaughter	1,000 head
COAHG	Acres harvested for grain, corn	1,000 acres
COAPL	Acres planted, corn	1,000 acres
COCCTP	Ending privately held free stocks, corn	Mil. bu.
COCIT	Beginning stocks, corn	Mil. bu.
COCOT	Ending stocks, corn	Mil. bu.
COPFM	Farm price, corn	$/bu.
COSPR	Production, corn	Mil. bu.
COSST	Total supply, corn	Mil. bu.
COUALC	Alcoholic beverage use, corn	Mil. bu.
COUALCPC	Per capita alcoholic beverage use, corn	Bu./person
COUFD	Food and industrial use, corn, uneven quarters	Mil. bu.
COUFDPCA	Per capita food and industrial use, corn, even quarters*	Bu./person
COUFE	Feed use, corn, uneven quarters	Mil. bu.
COUFEADJ	Adjusted feed use, corn, even quarters*	Mil. bu.
COUSE	Seed use, corn	Mil. bu.
COUUT	Total utilization, corn	Mil. bu.
COYHG	Yield per harvested acre, corn	Bu./acre
CVPFM	Calf price, farm	$/cwt
CVQ	Annual calf crop	1,000 head
CVQP	Annual calving rate	Proportion
CWK	Cow inventory, January 1	1,000 head
CWQ	Cow slaughter	1,000 head
CWQA	Annual cow slaughter*	1,000 head
FGPFM	Feed price—weighted average of corn price and soybean meal price*	$/cwt
HFG5K	Heifers over 500 pounds on farms, January 1	1,000 head
HFN	Heifers actually entering the cow herd	1,000 head
HFNP	Proportion of heifers kept for replacement that actually enter the cow herd	Proportion
HFR	Heifers kept for cow replacement	1,000 head
HOBGQ	Barrow and gilt slaughter	1,000 head

*See arithmetic expressions for constructed variables at end of table.

Continued—

Quarterly agriculture forecasting model variable definitions—Continued

Variables	Definition	Units
Endogenous, continued		
HOBRQ	Boar slaughter	1,000 head
HOPFM	Hog price, farm	$/cwt
HOPGQ	Pig crop, 10 States	1,000 head
HOP7M	Barrow and gilt price, seven markets	$/cwt
HOP7MWA3	Moving weighted average of HOP7M*	$/cwt
HOQ	Hog slaughter	1,000 head
HOSWF	Sows farrowing, 10 States	1,000 head
HOSWQ	Sow slaughter	1,000 head
OTHERPOQT	Meat and poultry production less pork production*	Mil. lbs.
OTHERTUQT	Meat and poultry production less turkey production*	Mil. lbs.
POCIT	Beginning pork stocks, cold storage	Mil. lbs.
POCOT	Ending pork stocks, cold storage	Mil. lbs.
POQC	Pork production, commercial	Mil. lbs.
POQT	Pork production, total	Mil. lbs.
POSST	Total pork supply	Mil. lbs.
POUCCC	Civilian pork consumption, carcass weight	Mil. lbs.
POUCCCPC	Civilian per capita pork consumption, carcass weight	Pounds/person
POUCCRPC	Civilian per capita pork consumption, retail weight	Pounds/person
PR7LV	Livestock price index	1977 = 100
SBAHB	Acres harvested, soybeans	1,000 acres
SBAPL	Acres planted, soybeans	1,000 acres
SBCIT	Beginning stocks, soybeans	Mil. bu.
SBCOT	Ending stocks, soybeans	Mil. bu.
SBPFM	Farm price, soybeans	$/bu.
SBSPR	Production, soybeans	Mil. bu.
SBSST	Total supply, soybeans	Mil. bu.
SBUCR	Soybean crush, even quarters	Mil. bu.
SBUCRUN	Soybean crush, uneven quarters	Mil. bu.
SBUUTUN	Total use, soybeans, uneven quarters	Mil. bu.
SBYHB	Yield per harvested acre, soybeans	Bu./acre
SMCIT	Beginning stocks, soybean meal	1,000 tons
SMCOT	Ending stocks, soybean meal	1,000 tons
SMPDM	Soybean meal price, Decatur, 44-percent protein	$/ton
SMSPR	Production, soybean meal	1,000 tons
SMSST	Total supply, soybean meal	1,000 tons
SMUDT	Domestic use, soybean meal	1,000 tons
SMUUT	Total use, soybean meal	1,000 tons
SMYCR	Crushing yields, soybean meal	tons/1,000 bu.
SOCIT	Beginning stocks, soybean oil	Mil. lbs.
SOCOT	Ending stocks, soybean oil	Mil. lbs.
SOPDM	Soybean oil price	Cents/lb.
SOSPR	Production, soybean oil	Mil. lbs.
SOSST	Total supply, soybean oil	Mil. lbs.
SOUDT	Total domestic use, soybean oil	Mil. lbs.
SOUDTPC	Per capita domestic use, soybean oil	Pounds/person
SOUUT	Total use, soybean oil	Mil. lbs.
SOYCR	Crushing yields, soybean oil	Lbs./bu.
STEP	Feeder steer price	$/cwt
STEPA	Feeder steer price, annual*	$/cwt
STEPWA3	Moving weighted average of STEP*	$/cwt
STFP	Fed steer price	$/cwt
STFPWA3	Moving weighted average of STFP*	$/cwt
STG5K	Steers over 500 pounds on farms, January 1	1,000 head
STHFFQ	Fed steer and heifer slaughter	1,000 head
STHFNFQ	Nonfed steer and heifer slaughter	1,000 head
STHFTQ	Total steer and heifer slaughter	1,000 head
TUCIT	Beginning stocks, turkeys	1,000 lbs.

See footnotes at end of table.

Continued—

Quarterly agriculture forecasting model variable definitions—Continued

Variables	Definition	Units
Endogenous, continued		
TUCOT	Ending stocks, turkeys	1,000 lbs.
TUPFM	Turkey price, farm	$/cwt
TUQ	Turkey production	1,000 lbs.
TUSST	Total turkey supply	1,000 lbs.
TUUCC	Civilian consumption, turkeys	1,000 lbs.
TUUCCPC	Civilian pér capita consumption, turkeys	Pounds/person
WHAHG	Acres harvested for grain, wheat	1,000 acres
WHAPL	Acres planted, wheat	1,000 acres
WHCCTP	Ending privately held free stocks, wheat	Mil. bu.
WHCIT	Beginning stocks, wheat	Mil. bu.
WHCOT	Ending stocks, wheat	Mil. bu.
WHPFM	Farm price, wheat	$/bu.
WHSPR	Production, wheat	Mil. bu.
WHSST	Total supply, wheat	Mil. bu.
WHUFD	Food use, wheat	Mil. bu.
WHUFDPC	Per capita food use, wheat	Bu./person
WHUFE	Feed use, wheat	Mil. bu.
WHUSE	Seed use, wheat	Mil. bu.
WHUUT	Total utilization, wheat	Mil. bu.
WHYHG	Yield per harvested acre, wheat	Bu./acre
Exogenous		
BAPFM	Farm price, barley	$/bu.
BEQF	Beef production, farm	Mil. lbs.
BESMT	Beef imports	Mil. lbs.
BEUML	Beef consumption, military	Mil. lbs.
BEUSH	Beef shipments	Mil. lbs.
BEUXT	Beef exports	Mil. lbs.
BRUML	Broiler consumption, military	1,000 lbs.
BRUSH	Broiler shipments	1,000 lbs.
BRUXT	Broiler exports	1,000 lbs.
COCCTC	Ending stocks under CCC loan, corn	Mil. bu.
CODP	Houck-Ryan corn diversion payment rate	$/bu.
COFOR	Ending farmer owned reserve stocks, corn	Mil. bu.
COFOREX	Ending extended FOR stocks, corn	Mil. bu.
CONEN	Government owned (CCC) stocks, corn	Mil. bu.
COPHR	Houck-Ryan effective corn price	$/bu.
COSMT	Imports, corn	Mil. bu.
COTA	Annual time trend for corn crop year	1966 crop year = 1
COUXT	Exports, corn	Mil. bu.
CPI	Consumer price index	1967 = 100
Di	Dummy variable equal to 1 in the i-th quarter, i = 1, 2, 3, 4	N.A.
D70	Annual dummy variable equal to 1 in 1970	N.A.
D71	Annual dummy variable equal to 1 in 1971	N.A.
D73MY	Annual dummy variable equal to 1 in the 1973/74 soybean marketing year (fourth quarter 1973 through third quarter 1974)	N.A.
D7302	Dummy variable equal to 1 in the second quarter, 1973	N.A.
D7303	Dummy variable equal to 1 in the third quarter, 1973	N.A.
D74	Annual dummy variable equal to 1 in 1974	N.A.
D7401	Dummy variable equal to 1 in the first quarter, 1974	N.A.
D7603	Dummy variable equal to 1 in the third quarter, 1976	N.A.
D78	Annual dummy variable equal to 1 in 1978	N.A.
D79	Annual dummy variable equal to 1 in 1979	N.A.
D80	Annual dummy variable equal to 1 in 1980	N.A.
D8003	Dummy variable equal to 1 in the third quarter, 1980	N.A.

*See arithmetic expressions for constructed variables at end of table.

Continued—

Quarterly agriculture forecasting model variable definitions—Continued

Variables	Definition	Units
Exogenous, continued		
D8103F03	Dummy variable equal to 1 in all third quarters beginning in 1981	N.A.
EGPFM	Egg price, farm	$/cwt
GNPDA	GNP deflator, annual	1972 = 100
HAPFC	Hay price	$/ton
HAPFMSA	Hay price, annual, season average	$/ton
HOADW	Hogs, average dressed weight, commercial production	Pounds
HOPGQRAT	Pigs saved per litter, 10 States	Number
JP	July precipitation, Corn Belt	Inches
JT	July temperature, Corn Belt	Degrees (F)
MIPFM	Milk price, farm	$/cwt
PCED	Personal consumption expenditures deflator	1972 = 100
POCRWGT	Pork, carcass-to-retail weight conversion factor	Proportion
POP	Total U.S. population	Millions
POPCIV	Civilian population	Millions
POQF	Pork production, farm	Mil. lbs.
POSMT	Pork imports	Mil. lbs.
POUML	Pork consumption, military	Mil. lbs.
POUSH	Pork shipments	Mil. lbs.
POUXT	Pork exports	Mil. lbs.
PPFZ2	Fertilizer price index, second quarter	1977 = 100
SBTA	Annual time trend for soybean crop year	1966 crop year = 1
SBUSFRUN	Soybean feed and residual, uneven quarters	Mil. bu.
SBUXT	Soybean exports, even quarters	Mil. bu.
SBUXTUN	Soybean exports, uneven quarters	Mil. bu.
SMUXT	Soybean meal exports	1,000 tons
SOUXT	Soybean oil exports	Mil. lbs.
TA	Annual time trend	1966 = 1
TQ	Quarterly time trend	1960:1 = 1
TUUML	Turkey consumption, military	1,000 lbs.
TUUSH	Turkey shipments	1,000 lbs.
TUUXT	Turkey exports	1,000 lbs.
WHCCTC	Ending stocks under CCC loan, wheat	Mil. bu.
WHDP	Houck-Ryan wheat diversion payment rate	$/bu.
WHFOR	Ending farmer owned reserve stocks, wheat	Mil. bu.
WHNEN	Government owned (CCC) stocks, wheat	Mil. bu.
WHPHR	Houck-Ryan effective wheat price	$/bu.
WHSMT	Imports, wheat	Mil. bu.
WHTA	Annual time trend for wheat crop year	1966 crop year = 1
WHUXT	Exports, wheat	Mil. bu.
Y	Personal disposable income, nominal	Bil. dol.
YMA4	Four quarter moving average of income*	Bil. dol.
YMA4LC	Change in the log of YMA4	Bil. dol.
YMA8	Eight quarter moving average of income*	Bil. dol.
YMA8LC	Change in the log of YMA8	Bil. dol.

N.A. = Not applicable.

*Arithmetic expressions:

$BRPLWS3 = BRPL + 0.80\ BRPL_{t-1} + 0.61\ BRPL_{t-2}$

$COUFDPCA = COUFD\ [D1 + D2(3/2) + D3(3/4) + D4]/POP$

$COUFEADJ = COUFE\ [D1 + D2(3/2) + D3(3/4) + D4]$

$CWQA = D4\ (CWQ + CWQ_{t-1} + CWQ_{t-2} + CWQ_{t-3})$

$FGPFM = 0.70\ (COPFM/0.56) + 0.30\ (SMPDM/20)$

$HOP7MWA3 = (3.0\ HOP7M_{t-1} + 2.0\ HOP7M_{t-2} + HOP7M_{t-3})/6$

$OTHERPOQT = BEQT + BRQ/1000 + TUQ/1000$

$OTHERTUQT = BEQT + POQT + BRQ/1000$

$STEPA = D4\ (STEP + STEP_{t-1} + STEP_{t-2} + STEP_{t-3})$

$STEPWA3 = (3.0\ STEP_{t-1} + 2.0\ STEP_{t-2} + STEP_{t-3})/6$

$STFPWA3 = (3.0\ STFP_{t-1} + 2.0\ STFP_{t-2} + STFP_{t-3})/6$

$$YMA4 = \sum_{i=0}^{3} Y_{t-i}/4 \qquad YMA8 = \sum_{i=0}^{7} Y_{t-i}/8$$

Appendix C—Construction of the Houck-Ryan Variables

The planted acres equations in the crop sector use the Houck-Ryan (*14*) approach to incorporating price and policy variables in the model. This approach uses effective price variables for payments of the crop produced and diversion payment variables. In each case, adjustments are made to represent the commodity program requirements in place for a given year. And for each year, the value used for each variable is the average value between the alternatives of minimum and maximum levels of participation in the program.

Houck-Ryan effective price variables and diversion payment variables are used in the model for corn and wheat. However, soybean farm price is appropriately used without policy adjustments. This is because over the estimation period there were no soybean acreage control programs, soybean farm price was higher than the support rate, and there was no paid diversion program for soybeans.

To illustrate the construction of the Houck-Ryan variables used, derivations of the effective corn price (COPHR) and the corn diversion rate (CODP) for 1972 are shown. The support price for corn was $1.41 per bushel guaranteed on half the base acreage; price expectation (assumed in the modified "cobweb" framework to be the first quarter 1972 price) was $1.09; the set-aside rate was 25 percent; and an optional 20-percent additional set aside was in place with a 52-cent-per-bushel payment on all unplanted acreage. For participation in the program at the minimum level (25-percent set aside), the effective Houck-Ryan price would be the support price (since it exceeds the price expectation) times the fraction of base acreage covered by support (0.50) plus the remaining fraction of base acreage that could be planted (0.25) times the expected market price. No diversion payment is made at the minimum level of participation. Therefore, for minimum participation:

$$COPHR_{min} = 0.5\ (1.41) + 0.25\ (1.09) = 0.9775$$
$$CODP_{min} = 0$$

At the maximum level of participation (additional 20 percent of base set aside) the fraction of base acreage covered by support (multiplied by the $1.41 support price) is again 0.50, while the remaining fraction of base acreage that could be planted (multiplied times the $1.09 expected market price) is now 0.05. Under the additional 20-percent set-aside option, all unplanted base acreage (0.45 of base) is paid at a rate of 52 cents per bushel. So, for maximum participation:

$$COPHR_{max} = 0.5\ (1.41) + 0.05\ (1.09) = 0.7595$$
$$CODP_{max} = 0.45\ (0.52) = 0.234$$

Averaging over the minimum and maximum, the values used in the model are:

$$COPHR = 0.8685$$
$$CODP = 0.117$$

For wheat, a similar process is followed to construct the Houck-Ryan variables. However, the price expectations variable for wheat in the modified "cobweb" framework is the previous third-quarter price, the last observable price prior to winter wheat plantings.

No attempt was made in the construction of the Houck-Ryan variables to handle set asides differently from reduced acreage programs. Also, no attempt to adjust for "program yields" versus "actual yields" was made. Finally, the policy parameters used here each year were the final values of those parameters. No attempt was made to adjust those parameters in years when policy changes were made following plantings.

Appendix D—Specifications of Additional Equations and Variable Definitions

Specifications of additional equations

Corn sector, additional equation specifications

1. Change in corn stocks under CCC loan[1]

$$\mathrm{COCCTCD} = -46.02 + \underset{(5.46)}{0.0505}\ \mathrm{COSPR{\cdot}D4} - \underset{(3.78)}{173.10}\ \mathrm{COPFM} + \underset{(3.60)}{173.60}\ \mathrm{COPFM}^{e} + \underset{(3.99)}{115.49}\ \mathrm{COPLC{\cdot}(D4 + D1)}$$

$$- \underset{(4.71)}{147.00}\ [\mathrm{COPLC{\cdot}(D4 + D1)}]_{t-3} - \underset{(2.78)}{82.03}\ \mathrm{COPLF{\cdot}(D4 + D1){\cdot}DFORD{\cdot}DFORE}$$

$$+ \underset{(3.31)}{104.77}\ [\mathrm{COPLF{\cdot}(D4 + D1){\cdot}DFORD{\cdot}DFORE}]_{t-3}$$

$R^2 = 0.745$ RMSE = 108.75 CV = 27.90 Estimation period = 1967-1981

2. Change in privately held corn stocks[1]

$$\mathrm{COCCTPD} = -724.23 + \underset{(49.33)}{0.825}\ \mathrm{COSPR{\cdot}D4} - \underset{(5.89)}{0.164}\ \mathrm{COCCTP}_{t-1} - \underset{(2.55)}{90.83}\ \mathrm{COPFM} - \underset{(3.48)}{153.74}\ \mathrm{COPLF{\cdot}(D4 + D1){\cdot}DFORE} + \underset{(3.48)}{498.51}\ \mathrm{D2}$$

$R^2 = 0.994$ RMSE = 186.65 CV = 8.24 Estimation period = 1967-1981

3. Corn price

$$\mathrm{COPFM} = -0.358 + \underset{(10.1)}{0.718}\ \mathrm{COPFM}_{t-1} + \underset{(3.8)}{1.98}\ \mathrm{D1\,(COCFRE/COUUTADJ)}^{-1} + \underset{(3.6)}{1.46}\ \mathrm{D2(COCFRE/COUUTADJ)}^{-1}$$

$$+ \underset{(4.1)}{0.551}\ \mathrm{D3(COCFRE/COUUTADJ)}^{-1} + \underset{(3.3)}{2.35}\ \mathrm{D4(COCFRE/COUUTADJ)}^{-1}$$

$R^2 = 0.888$ RMSE = 0.23 CV = 10.13 Estimation period = 1971-1981

Wheat sector, additional equation specifications

4. Change in wheat stocks under CCC loan[1]

$$\mathrm{WHCCTCD} = 139.35 + \underset{(2.88)}{0.0485}\ \mathrm{WHSPR{\cdot}D3} - \underset{(2.47)}{45.65}\ \mathrm{WHPFM} + \underset{(2.20)}{40.15}\ \mathrm{WHPFM}^{e} + \underset{(4.25)}{46.23}\ \mathrm{WHPLC{\cdot}(D3 + D4)}$$

$$- \underset{(1.59)}{16.08}\ [\mathrm{WHPLC{\cdot}(D3 + D4)}]_{t-3} - \underset{(4.22)}{0.223}\ \mathrm{WHCCTC}_{t-1} + \underset{(1.71)}{7.86}\ (\mathrm{RTB} - \mathrm{RCCCWH}) - \underset{(3.81)}{0.497}\ \mathrm{WHUXT} + \underset{(3.81)}{362.63}\ \mathrm{D7703}$$

$R^2 = 0.722$ RMSE = 55.87 CV = 21.31 Estimation period = 1967-1981

5. Change in privately held wheat stocks[1]

$$\mathrm{WHCCTPD} = 20.28 + \underset{(19.11)}{0.661}\ \mathrm{WHSPR{\cdot}D3} - \underset{(6.11)}{0.322}\ \mathrm{WHCCTP}_{t-1} + \underset{(2.66)}{43.80}\ \mathrm{WHPFM}^{e} - \underset{(3.55)}{16.20}\ \mathrm{RTB} - \underset{(2.17)}{85.06}\ \mathrm{D1} - \underset{(1.43)}{77.58}\ \mathrm{D2}$$

$R^2 = 0.986$ RMSE = 86.14 CV = 10.04 Estimation period = 1967-1981

6. Wheat price

$$\mathrm{WHPFM} = 0.0183 + \underset{(13.4)}{0.837}\ \mathrm{WHPFM}_{t-1} + \underset{(2.1)}{0.878}\ \mathrm{D1(WHCFRE/WHUUTADJ)}^{-1} + \underset{(1.0)}{0.246}\ \mathrm{D2(WHCFRE/WHUUTADJ)}^{-1}$$

$$+ \underset{(2.8)}{2.06}\ \mathrm{D3(WHCFRE/WHUUTADJ)}^{-1} + \underset{(3.3)}{2.02}\ \mathrm{D4(WHCFRE/WHUUTADJ)}^{-1}$$

$R^2 = 0.876$ RMSE = 0.39 CV = 12.64 Estimation period = 1971-1981

[1]For the stocks equations, the coefficient of variation (CV) is calculated with the mean of the level of the stocks variable as the denominator.

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Variable definitions

Variables	Definition	Units
COCCTCD	Change in ending stocks under CCC loan, corn	Mil. bu.
COCCTP	Ending privately held stocks, corn	Mil. bu.
COCCTPD	Change in ending privately held stocks, corn	Mil. bu.
COCFRE	Ending free stocks (total minus CCC-owned minus FOR), corn	Mil. bu.
COPFM	Farm price, corn	$/bu.
$COPFM^e$	Expected farm price, corn[1]	$/bu.
COPLC	CCC loan rate, corn	$/bu.
COPLF	FOR loan rate, corn	$/bu.
COSPR	Production, corn	Mil. bu.
COUUT	Total utilization, corn	Mil. bu.
COUUTADJ	Total utilization, adjusted, corn[1]	Mil. bu.
DFORD	Dummy variable equal to 1 when the corn FOR is open for direct entry	N.A.
DFORE	Dummy variable equal to 1 starting when the corn FOR was created	N.A.
Di	Dummy variable equal to 1 in the i-th quarter, i = 1, 2, 3, 4	N.A.
D7703	Dummy variable equal to 1 in the third quarter 1977	N.A.
RTB	Interest rate, 3-month Treasury bill	Percent
RCCCWH	Interest rate, CCC commodity loan rate	Percent
WHCCTC	Ending stocks under CCC loan, wheat	Mil. bu.
WHCCTCD	Change in ending stocks under CCC loan, wheat	Mil. bu.
WHCCTP	Ending privately held stocks, wheat	Mil. bu.
WHCCTPD	Change in ending privately held stocks, wheat	Mil. bu.
WHCFRE	Ending free stocks (total minus CCC-owned minus FOR), wheat	Mil. bu.
WHPFM	Farm price, wheat	$/bu.
$WHPFM^e$	Expected farm price, wheat[1]	$/bu.
WHPLC	CCC loan rate, wheat	$/bu.
WHSPR	Production, wheat	Mil. bu.
WHUUT	Total utilization, wheat	Mil. bu.
WHUUTADJ	Total utilization, adjusted, wheat[1]	Mil. bu.
WHUXT	Exports, wheat	Mil. bu.

N.A. = Not applicable.

[1]COUUTADJ = COUUT [D1 + D2(3/2) + D3(3/4) + D4]

WHUUTADJ = WHUUT [D1 + D2(3/2) + D3(3/4) + D4]

$$COPFM^e = \sum_{i=1}^{4} COPFM_{t-i}/4 \qquad WHPFM^e = \sum_{i=1}^{4} WHPFM_{t-i}/4$$